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THE

REPAIR AND MAINTENANCE

OF

MACHINERY.

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A HANDBOOK OF PRACTICAL NOTES AND MEMORANDA FOR ENGINEERS AND MACHINERY USERS.

BY

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H.R.T

PREFACE.

THE manufacture and erection of new machinery is one thing, and to keep it in good order and repair damages is another and very different affair. It almost involves a different set of faculties, for an engineer employed always on new work is entirely unfitted to cope with the peculiar difficulties and problems constantly presented to the repairer. A good hand, therefore, for this work, must have had much general experience and be possessed of some originality to be successful.

Engineers' shops are more or less occupied with repairing work, which, from its drawbacks and difficulties, is often more tolerated than sought after. Workmen avoid it as much as possible, because it is not straightforward work, dirty and difficult to deal with.

To help to some extent to remove or reduce these difficulties, is the author's purpose in the following pages, which deal with most of the general classes of machinery in use. There are, of course, a great many machines that could not with any advantage be separately specified and described, but it is hoped that a perusal of those particularised in the various sections may give many hints necessary for dealing with cases not directly enumerated.

Besides mere repairing, however, an engineer is frequently called upon to remedy defects of design or installation, and to do this effectively requires an intimate knowledge of the

class of machinery under treatment. Many of these defects, as they have been brought to the author's notice, are pointed out and the remedies suggested. It can hardly be expected that any engineer can have a thorough acquaintance with every general or particular class of machines, but a good all-round experience and natural ability will generally enable us to prescribe remedies, even in unfamiliar pieces of mechanism.

Maintenance is as important in its way as repairing, and a knowledge of the proper management of machines, to avoid trouble and loss, of equal advantage with that of how to remedy faults, and may save much expense and loss of time.

This work is necessarily devoted especially to the defects and faults to be found more or less in all machines, and has therefore but little to do with their virtues and excellencies, but it must not be assumed that the machines dealt with are necessarily full of defects, or that they have no points of excellence. A repairer is familiar chiefly with the seamy side of engineering, and often becomes an inveterate grumbler, and though the task is not always pleasant, some one must point out faults, and if possible, indicate methods of remedying them.

It is hoped, therefore, that the author's strictures will be taken as intended, as hints indicating possible openings for improvement, and not merely as fault finding.

T. W. BARBER.

HASTINGS: 1894.

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REPAIR AND MAINTENANCE OF MACHINERY.

SECTION I.—*STEAM BOILERS.*

CHAPTER I.

NOTES ON STEAM BOILERS.

OF the extensive and increasing varieties of steam generators that the practical engineer is called upon to deal with, it is needless to specify every type and pattern, but it will be, perhaps, convenient and more acceptable to the reader if we deal with boilers generally in the first instance, and then proceed to point out where, in special types or instances, special treatment is required; and the same plan will be adopted, as far as practicable, throughout this work.

Causes of Deterioration generally and Strains on Steam Boilers.—We may divide boilers into three general classes: (1) boilers constructed of plate work, with or without tubular flues; (2) water tube boilers, that is, boilers constructed of tubes, with or without plate work; (3) cast-iron boilers and domestic boilers generally.

Few persons realise the irregular and variable nature of the strains set up in boilers, both in course of manufacture and working, and to which strains, in a great measure, the rapid deterioration and frequent failures are due. Other causes are, of course, corrosion, internally, from acids, impurities, natural sediment in the feed water, and externally, from leakages and burning of the plates and rivets, besides

galvanic action, which, while it undoubtedly is an important factor, is but little understood.

To comprehend to some extent the effects of these causes of deterioration, let us take the case of an ordinary Cornish boiler, that is, a simple cylindrical shell with flat ends and one plate flue. And, firstly, as to the strains set up in course of manufacture; the plates as turned out from the rolling mill, from unequal cooling and more or less want of homogeneity of metal, are subject to internal strains, the direction and intensity of which it is almost impossible to gauge, but are very apparent by their buckled and warped condition. They are then sheared and (commonly) punched along the edges for the rivets, corners heated and tapered, some plates drawn on the ring seam edges by rolling, others flanged and dished when heated, all which operations, by impressing work upon the structure of the metal, set up conflicting strains and impair the fibrous, and hence the tensile strength of the plates, reducing by so much per cent., and in a very irregular manner, the nett power of resistance of the boiler; the rivet holes also, by reducing the available section of the plates, considerably weaken them. When the boiler is set to work it is subject to a new series of strains, independent of the pressure of steam within it; at one end of the internal flue a furnace temperature of, say from 1000° to 2500° is maintained—not a constant temperature even—but liable to sudden falls when the fire is charged with fresh fuel or the fire door opened. The other end of the flue will have an internal temperature of, say 700° to 1200° to withstand, while the shell is subject to local temperatures varying from 600° to 300° in the flues, and merely atmospheric temperature on the exposed upper and front plates, or if these are coated, the steam temperature, while the inside surfaces of the plates are kept comparatively cool by the water and steam. Now, we know that iron plates expand ·0000066 per degree F., and can easily calculate, therefore, that the different portions of the plates are liable to expansions of from ·00887 to ·198 inches per foot, lineally. It is not difficult thus to see that these varying and unequal expansions, added to the steam

pressure, all the strains being continually shifting, tend materially to reduce, if not ultimately to destroy the structure and power of resistance of the plates, the intensity of the strains being greatly augmented in the more complex types of plate work boilers.

It is not our province to point out a remedy for the evil, beyond stating the obvious conclusion that it must be found in improved material or modes of working the plates, and in means of more evenly distributing the temperatures; but, considering the frequent failures, and in view of the irregular nature of the working loads, it does seem to us that the usual factor of safety, of four, ordinarily adopted for steam boilers is too low, as compared with those employed for bridges and other structures subject to variable strains.

We now turn to consider the effects resulting from the strains set up in working the boiler in conjunction with the corrosive action of fire and water, and shall then better understand how to deal with them effectually.

The pressure of steam tends to straighten out the longitudinal seams, as in Fig. 5, page 5, the actual bending takes place chiefly at the edges of the seams D E, because the laps are stiffened by the rivets. At these points "grooving" frequently results internally (Figs. 6, 7 and 8), particularly in those seams which, from their position near the furnace or from other structural causes, are subject to the greatest changes of strain. End seams, being tied by the end plates and L-irons, cannot give and take so freely as other places. Man-hole and fire-hole seams are particularly liable to leakage, caused by unequal expansion and strains, and by lack of elasticity.

The circulation of the water, which is frequently very indifferent in the ordinary types of boilers, also causes local and unexpected corrosion. It has been proved that the temperature of water in an ordinary Cornish or Lancashire boiler may frequently vary from, say 100° at the bottom to 212° at the surface.

The feed water also, when supplied cold, causes injury to the plates and seams in the neighbourhood of its influx.

Sediment and scale, which settle chiefly on the upper sides of all internal surfaces and ledges, allow those portions of the plates to become overheated and burnt externally (Fig. 4), particularly those exposed to the direct heat of the furnace or its flame. Internally the sediment eats into and corrodes the plates, particularly at the lower seams, as in Figs. 1, 2 and 3.

Leakages generally cause the most important external corrosions, the constant drip or run of hot water causing rapid oxidation of the iron, and is very common round man and mud-holes, plugs and fittings generally. Every hole made in a boiler is liable to become a source of destruction,

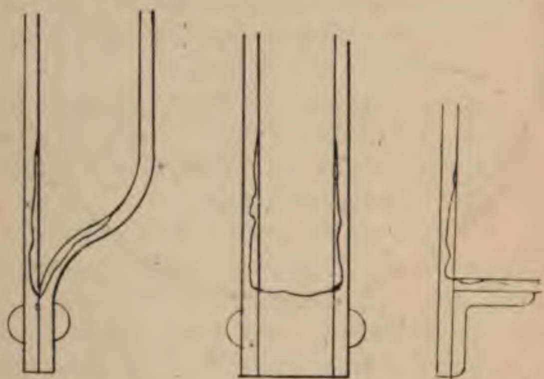


FIG. 1. FIG. 2. FIG. 3.

so that both in making and repairing it the fewer holes the better.

Of the various forms in which corrosion is met with, grooving or channelling is certainly the most important. It usually occurs at the joints of the plates to each other, or to some fittings or other parts of the boiler. Internally the effect is more generally due to the localisation of corrosion, owing to the fact that the plate at that part is subject to some bending action tending to disintegrate the surface, and thus facilitating any corrosive action of the feed water. Externally the grooving is generally due to leakage at or adjacent to the defective part, and unless there be brickwork or other materials in contact with the plates, the wasting is usually local.

The mechanical action which results in grooving at the longitudinal or ring seams, when the water is corrosive, is usually due to the fact that, owing to the lapping of the plates

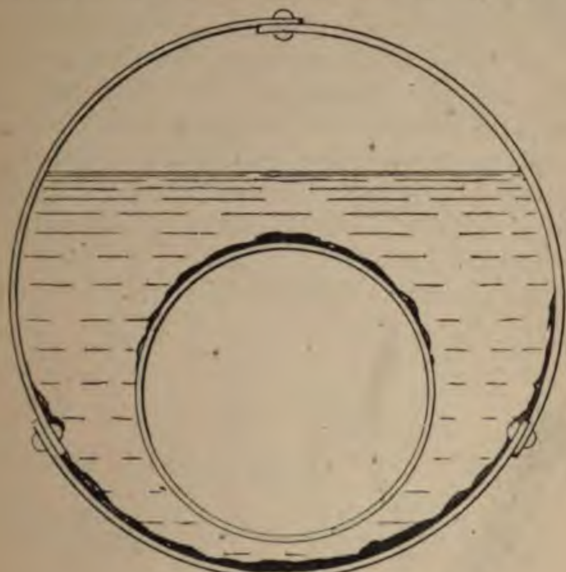


FIG. 4.

at the seams the stress is not transmitted directly, and a certain bending action is therefore set up close to the lap of the seam. This action may generally be noted when lap

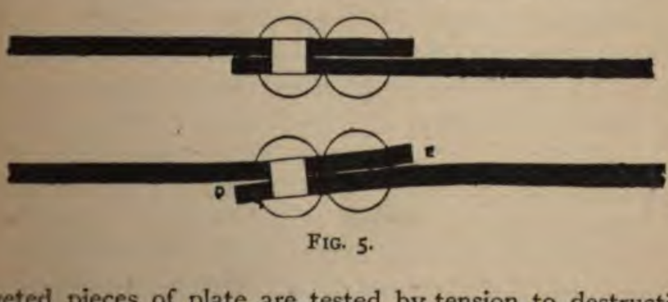


FIG. 5.

riveted pieces of plate are tested by tension to destruction. The upper of the annexed sketches (Fig. 5), shows two pieces of plate before stress has been put on them. When under

severe strain, the action referred to above results in the edge of the joint opening, and bending taking place at the points marked D and E in the lower sketch. The same action, though to a less degree, occurs in an ordinary boiler shell, both at the longitudinal and ring seams, when these are lapped, the variations of steam pressure from time to time causing an alternate bending to and fro, rendering the plate adjacent to the lap more vulnerable, and, with corrosive water, frequently resulting in more or less severe grooving. The annexed figure (Fig. 6) illustrates a case detected by a boiler inspector, thus avoiding disaster. This grooving was deep, and nearly penetrated the plate, as shown on the cross section, and extended almost continuously across the plate.*

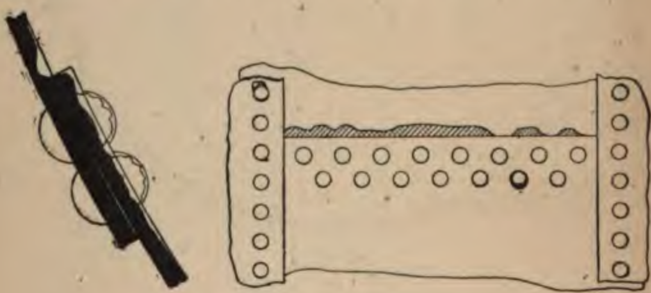


FIG. 6.

Occasionally cases are met with where the grooving is of a much more acute form than that illustrated above, the grooving being very narrow and deep, more like a fine fracture or nick. One of these grooves was recently detected in a locomotive. Grooving of this particular character has been responsible for a number of explosions of locomotive boilers, and has been found to occur where other parts of the boiler did not show the water to be of a violently corrosive nature. It is probably to be attributed, in the first instance, mainly to punishment and straining of the plates in construction. It would appear that some makers of locomotive boilers do not

* From notes and illustrations supplied by the Engineer of the National Boiler and General Insurance Co., Limited, 22 St. Ann's Square, Manchester.

construct the boiler shells with the same care which is taken with the manufacture of high-class "Lancashire" boilers. Locomotive boilers, although intended for high pressures, in many cases are often made with the rivet holes in the shell plate *punched before the plates are bent.* When this is done, it is difficult to avoid undue bending and distress being caused near the line of rivet holes when rolling the plate to form, and, in some instances, the final bending of the plate near the edges has been done by means of a sledge hammer. Where a plate has been treated in this way there is no reason for surprise if grooving, as described above, afterwards occurs, and, in view of the high pressures which are used in locomotive boilers, and the mechanical straining to which the boilers would appear to

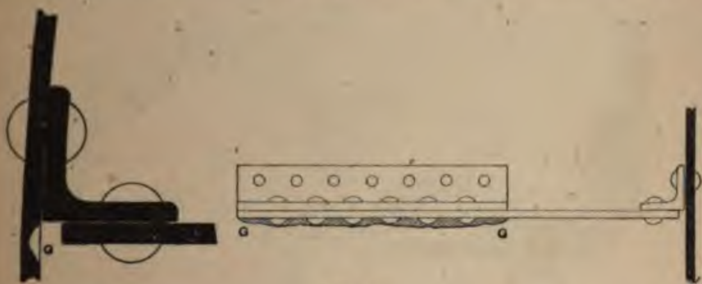


FIG. 7.

be subjected in the course of their working, owing to shaking in passing round curves, &c., it is of the highest importance that their construction should be on the best possible lines. Shells should be constructed of mild steel plates, each ring being made from one plate, with the longitudinal seams fixed above the water level, these being butt joints with double strips. All the rivet holes should be drilled after the plates have been bent to form.

When lap seams are under compression, as in the longitudinal seams of furnace tubes of "Lancashire" and "Cornish" boilers, a similar action to that described on page 5 takes place, though in a reverse manner, and grooving is frequently met with at these parts, a deep channel, G, being formed (Fig. 7) extending the full length of the angle attaching the

gusset plate to the shell. This is probably caused by mechanical action due to the gusset plate drawing the shell a little from the true circular form.

Grooving of the end plates above the furnaces is probably the commonest and least dangerous form of this defect. It occurs in " Lancashire " and " Cornish " boilers, being generally more severe at the front than the back end, and is due to the bending of the end plates owing to the expansion of the flue and furnace tubes. The local high temperature at the furnace end of the tube causes the "hogging" of the tube due to the above cause to be more severe at the front than the back end, and the grooving of the front end resulting is generally deeper than at the back end. Where ends are properly stayed such

FIG. 8.

grooving is seldom dangerous, although it may necessitate expensive repairs. Fig. 8 illustrates a case of this grooving in which the tube was attached to the end plate by an angle ring, and the same movement which caused the grooving, G, of the end also resulted in a groove, A, being formed in the bend of the angle iron. In tubes which are constructed with ring seams, lapped and riveted in the ordinary way, the small movements due to same cause—unequal expansion—frequently cause grooving at the furnace and flue tube ring seams.

A common and serious form of grooving is that which is met with on the furnace crown plates of ordinary vertical boilers, and is generally due to the straining of the plate near the connection to the chimney tube, arising from the difference

between the vertical expansion of the furnace plates and chimney tube and that of the shell. This expansion is at times unusually great, as these chimney tubes in the steam space very often become much over heated. Fig. 9 shows grooving, G, of this kind round the base of the chimney tube. The overheating and consequent excessive expansion of the chimney tube, which is largely responsible for this form of grooving, may be greatly reduced by protecting it on the fire side by a cast-iron liner or similar appliance.

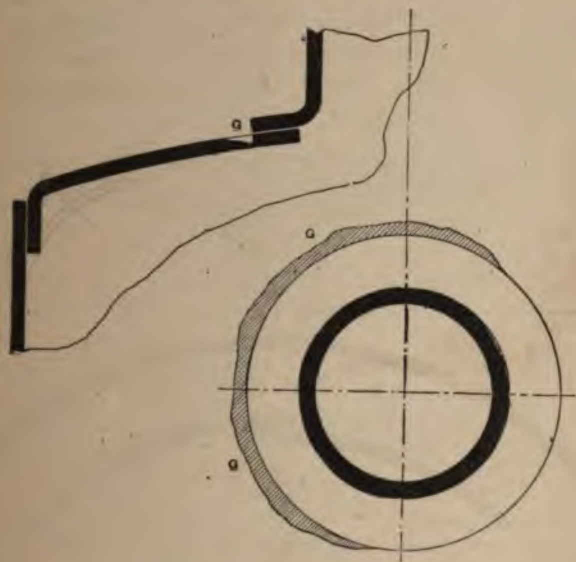


FIG. 9.

It is to be regretted that only few vertical boilers are protected in this way, and generally it is to be remarked that though these boilers give rise to so large a number of serious explosions, their design and construction does not usually receive that care which is so desirable.

Various other forms of grooving are met with, and in fact it may generally be stated that wherever parts of boilers are in the course of ordinary work subject to material movement, either owing to alteration of form due to pressure or to changes

of temperature, grooving will take place if the water be at all corrosive.

In portable boilers the expansion of the fire-box causes movement of the stays, and frequently these are severely reduced at their junction to the fire-box casing plates. In boilers of this class, also, the corners of the flanges connecting the fire-box to the casing at the bottom are also much grooved arising from the same cause.

One of the commonest forms in which this occurs is that

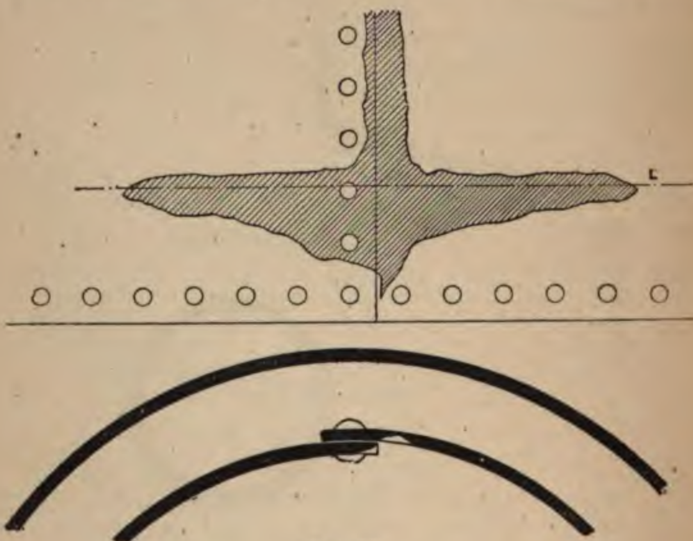


FIG. 10.

of grooving round the joint of some fitting block attached to the shell plate. This generally arises from leakage at the joint, and is more commonly met with in old boilers, to which the blocks are, in very many instances, connected by bolts. Another common form of the grooving occurs at the vertical seams of ordinary vertical boilers or of portable boilers (Fig. 10). The wasting is commonly confined to the part at which the leakage occurs, but if this should be near the fire-bar level, L, where the proximity of the bars may result in damp ashes being kept in contact with the plate, sometimes

more serious and extensive wasting results, as shown on the sketch.

In considering the case of an example of grooving, it must always be remembered that wasting at these parts is much more serious than corrosion to a similar depth at or near the centre of the plate. Internal grooving at longitudinal and ring seams, as before mentioned, may be ascribed usually to corrosion localised near the joint caused by slight bending to and fro at this part. The same mechanical action which results in grooving in the first instance tends to accentuate and cause it to be more acute near the lap of the plate afterwards. In determining the weakening effect of grooving, therefore, the strength of the grooved plate to resist this bending action must be taken into account, and in this connection it must be remembered that, generally speaking, the resistance of a plate to bending varies with the square of the thickness. It must usually be considered, therefore, in such cases that the ultimate resistance of the plate is reduced by grooving in a much greater ratio than is indicated by the ratio of the wasted thickness to the original thickness.

A large number of instances have been met with in which boilers have been very rapidly generally wasted on the water sides owing to the corrosive nature of the feed water.

In some of the large manufactuing towns in which processes are carried on involving the use of acid, it would appear that acid waste is occasionally turned into the streams. This most dangerous pollution has caused disastrous explosions in the past, and only recently we have met with cases where wasting of iron plates to a depth of $\frac{1}{8}$ inch to $\frac{3}{16}$ inch has been caused by pollution of this nature in less than twelve months.

Frequently wells are sunk and the water used for feeding boilers without any careful test having been made as to its suitability or otherwise. The water may be rendered unsuitable for the use of steam boilers by the presence of suspended matter, or by its excessive hardness or corrosive properties, and it is dangerous to use water for feeding until

its properties in these respects have been carefully determined. In several cases where wells have been recently sunk in large works and the water used for feeding the boilers, serious corrosion has been found to result, which, on investigation, proved to originate from a pollution of the water arising from leaky tanks containing acids from the works.

Many boilers at collieries and other mines are fed with water which has percolated through strata containing various minerals. In some cases this water is of a violently corrosive nature, and really unfit for use in steam boilers. In one district in this country where the attention to such matters has been rather backward in times past, boilers are very generally fed in the way described, and a considerable proportion of them have been found to be very seriously wasted by corrosion, the shell plates about the water level being especially reduced, in some instances to a maximum depth of $\frac{1}{4}$ inch. It appears to have been the practice in the particular cases referred to to cover the defective parts by means of plates bolted over them, the intervening space between the two plates being filled with red lead cement. The practice of concealing wasting in this way cannot be too strongly condemned. It has frequently led to an altogether erroneous idea being formed as to the boiler's strength, and disastrous explosion has followed. Wasting should never be concealed, but if not so serious as to require repair, it should be left open, so that the condition of the part may be regularly noted afterwards. The proper course, where feed water is found to be corrosive, is first to endeavour to procure a better supply of water. If this be impracticable, steps should be taken to have the water analysed so that the necessary methods of neutralising the acid properties of the water may be ascertained.

Other causes of injury are laminated plates (Fig. 11), defective punching or riveting, cracks running from rivet holes (Fig. 12), often not developed till after the boiler has seen some service, cracks at or near bent or dished plates, shortness of water, bad water, that is, containing a large percentage of oil, salt, acid, lime and other foreign matter, for

it must be remembered that everything that enters a boiler with the feed, except pure water, remains there and causes injury. Blowing off does little towards discharging sediment, because the current of discharge is too slow and too local. Tubes are liable to leakage at the tube plate, because of uneven expansion, or may collapse from weakening caused by

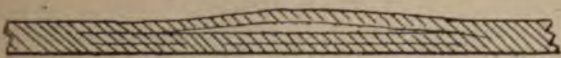


FIG. 11.

corrosion. Stays also sometimes cause leakage by continual expansion and contraction.

In water tube and multitubular boilers the principal failures are in the tube joints, which are numerous and often bad to get at. The pipes occasionally crack or burst.

Domestic boilers, which are seldom subject to much internal pressure, generally fail from burning, caused either by shortness of water, or more frequently sediment and corrosion. Those of wrought-iron plates are most frequently welded at the seams, the welds sometimes developing cracks, 'cold shuts' or burnt places, where the iron soon gives way. Of the greenhouse boiler there exists a marvellous variety of forms, all liable, however, to very similar defects and causes of ultimate failure similar to those already enumerated.

FIG. 12.

High pressure domestic boilers for heating baths, &c., are liable to burst from freezing of the water in the circulating pipes, when standing overnight or for a few days. When the fire is relighted, the water in the boiler will make steam long before the ice in the pipes is melted, because there is no circulation till the pipes are clear. Explosions from this cause are numerous and disastrous. A safety valve or plug should be fixed on these boilers, which will blow out when the pressure becomes greater than the static pressure of the water due to the natural head.

It may usefully be noted here that the old theory of explosions due to sudden inrush of feed or supply water into a dry overheated boiler, or upon an overheated furnace crown, causing sudden explosive generation of steam, is entirely contrary to both fact and theory, and has been experimentally disproved. Water will not touch a red hot plate, because a film of steam intervenes, and, as a matter of fact, the evaporation under such circumstances is not very rapid. The heat contained in the hot plate is not sufficient either to convert much of the water into steam; but a red hot boiler or furnace plate is soft, and offers but little resistance to pressure, so that a comparatively low pressure will then produce distortion or rupture, and cast-iron boilers will crack from contraction but not burst.

CHAPTER II.

BOILER REPAIRING.

BOILER repairing is probably the most unattractive of the multifarious jobs an engineer is called upon to execute. It is frequently required to be done during holidays, on Sundays, or at nights, to prevent stoppage of works, besides which, as the boiler can only rarely be brought to the tools, the tools have to be taken to the boiler and used in very constrained and difficult positions, often at high temperature with deafening noise and in a hot, dry and dusty atmosphere. It is not greatly surprising that boiler-makers as a class are not the best disciplined or most tractable mechanics.

The tools employed are chiefly ratchet brace and drills, drifts, reamers, taps, caulking tools, riveting tools, hammers and chisels, rivet forge, &c.

We will now deal with the most approved methods of repairing the various defects referred to in the first chapter.

Leakages. From rivet heads.—Caulk round the edge of

the rivet head, or if too far gone drill out and insert a new rivet. Drilling out is preferable to driving out as there is risk of cracking the plate in consequence of the frequent inaccurate punching, as shown in Fig. 13.

From seams or joints.—Caulking with a plain tool to close the metal of the external plate down on to the other as in

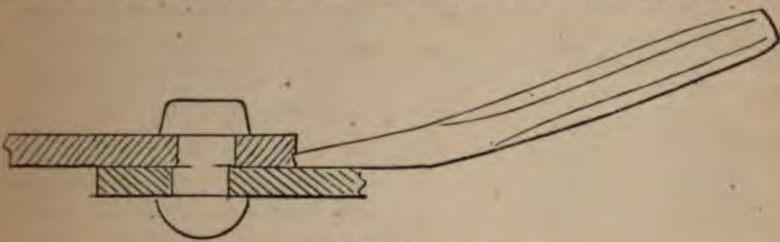
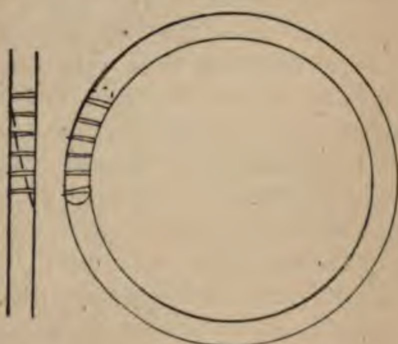


FIG. 13.

Fig. 13. Internal caulking is always more effective than external but cannot always be got at.

From mud-holes, plugs or fittings simply require new joint rings, as a rule. For man- and mud-holes the best ring is hard asbestos and rubber round packing (Figs. 14, 15) neatly scarfed at the joint, but such rings without joint can be purchased, some of which have fine wires woven in and can be used more than once. Hemp or spun yarn grummets (Fig. 16) (tarred yarn is best) are also used with red lead putty. Care must be taken with all these packings that they are well retained in the joint to prevent the possibility of blowing out. Serious accidents have followed in many cases from inefficient packing of man-holes, &c. Fittings should if possible be screwed into the boiler plate, and if internal back nuts are used they should be of brass, otherwise it is often impossible to get them off without cutting them



FIGS. 14, 15.

through. Back nuts, however, are not necessary, and give a great deal of trouble. Unsuspected leakages occur with some frequency in the flues and often cause serious damage before they are detected, especially at the seatings, or under brickwork or coated surfaces. Such places are often very difficult to deal with effectually, from the narrow space in the flues; in such cases the brickwork should be cut away sufficiently to allow of using the tools with some degree of freedom.

FIG. 16.

Corroded Plates. — When repairs are in hand, all the fractured, thinned, brittle or otherwise defective plates should be entirely renewed. If the boiler is old, or the holes in the plates adjacent to those removed be damaged by the removal of rivets or otherwise, cut off the old line of rivet holes and make fresh ones, carefully fit the new plates to the proper curve or shape, and be careful to retain the shell in perfectly cylindrical form. Unless the original plates are of inferior quality, the new plates, as a rule, should be of the same make, quality and thickness as the old ones. In repairing shell plates, care should be taken to avoid weakening the boiler by the adoption of a weaker riveted joint. The longitudinal seams should be arranged to "break-joint," and be double riveted if the seams of the old plates were made in this way.

Drilled holes are the best. Do not use the "drift" to open out mispunched holes, but "rimer" them out and use larger rivets to fill them; but if all the holes are bad, condemn the mispunched plate in preference to spoiling the work.

Whenever possible attach patches by rivets and not bolts, and do not apply small patches in the furnace parts of any kind of boiler.

Patching.—This is frequently required, especially in old boilers, and needs careful study in each case, as it often

ens that an entire new plate would be the cheapest and satisfactory repair. When the corroded spot is small a drilled and tapped, large enough to cut it out entirely, a wrought-iron plug screwed in and if possible riveted is often quite successful and easily effected. The plug ld be turned on end of a short bar (Fig. 17) and the ng tool run in, so as to leave re of metal strong enough rew in the plug, when the can be wrenched off and plug finished in the hole. er surfaces require pieces of r plate riveted over them s. 18 and 19), extending 3 or hes beyond the depression.

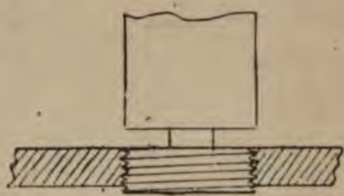


FIG. 17.

should be taken that the patch fits closely to the plate; this can be often done by beating it *in situ* hot. Plate copper is far more easily worked and

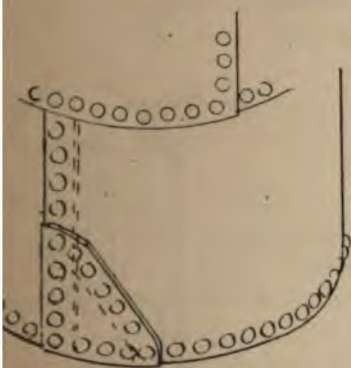


FIG. 18.

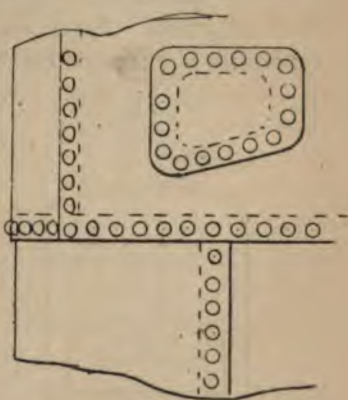


FIG. 19.

durable for patches than iron or steel, especially inside oxes, and will usually save the difference in cost in the spent in working and fixing it. When the patch ex- s to a seam it is desirable if possible to cut out the bad of the plate and bevil the seam, fitting the new patch ully to the seam. In all cases the patch should be

bolted up before riveting, to see that an accurate fit is obtained. In bad cases it becomes necessary to cut out a fire-box or

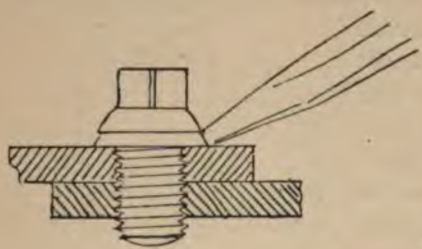


FIG. 20.

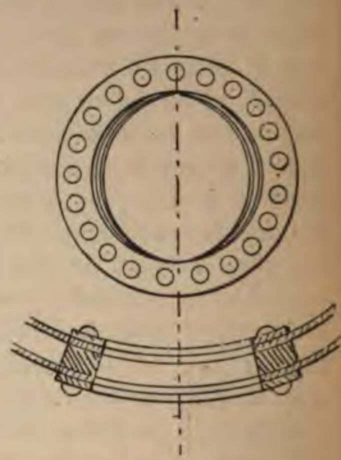


FIG. 21.

flue-tube entire, repair or replace it by a new one and then rivet in again. Such an extensive repair is very costly, especially if executed on the spot.

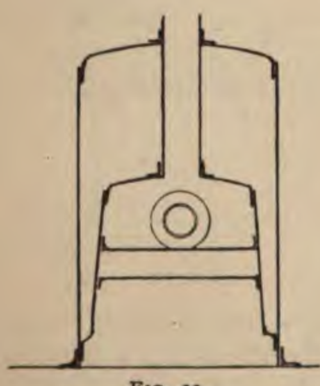


FIG. 22.

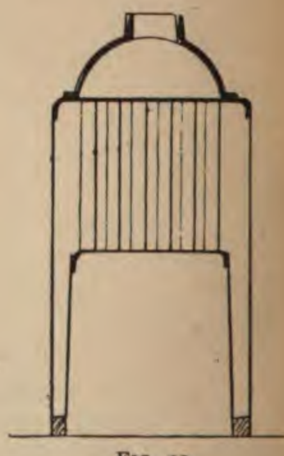


FIG. 23.

When it is difficult to rivet a patch it is usual to employ tapped rivets as set screws (Fig. 20), screwing them up by

the square on top of the head and afterwards caulking them round. With such rivets care must be taken to drill the holes and tap them exactly at right angles to the plate, or they will not screw up fair, but frequently break off.

Cup-head bolts and nuts are occasionally used where it is difficult to employ rivets, but, though they will pull up the joint nearly as efficiently as rivets, they are difficult to make watertight, especially near the furnace, besides which they do not fill the hole like a closed rivet and cannot be caulked as well. Such bolts should be of mild steel, as the quality

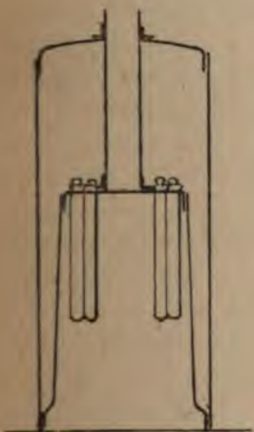


FIG. 24.

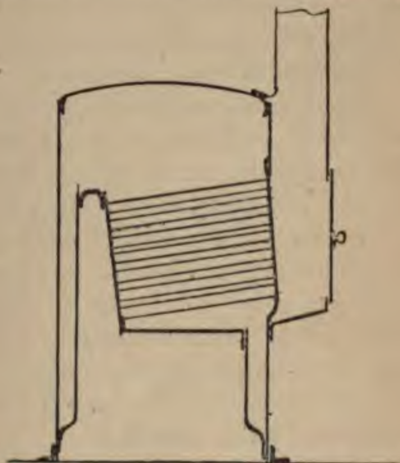


FIG. 25.

of iron bolts is seldom good enough, and small, tight, tarred yarn grummets used with a washer under the nut.

Man-holes, Mud-holes and Fire-holes are sometimes reinforced by a strengthening ring riveted on, both inside and out (Fig. 21) which if well fitted allows the joint between to be effectually caulked if leaky. Much care is required that the plates are pulled up close together by bolts before putting in rivets, as slight spaces cause the plates to spring away from the caulking tool; caulking one spot will then open another and cause a leak.

Vertical Boilers.—Of these there are many types, the principal of which are shown in the Figs. 22–25. The chief

defects of them all are the difficulty of cleaning, the bad circulation in the narrow water space round the fire-box, the violent ebullition and consequent priming on the surface of the water, besides particular faults which are referred to further on.

Small vertical boilers such as are usually used for fire engines, work under peculiar conditions, and they are generally of special construction to meet the requirements of the case. For convenience of rapid transport, the plates are usually as light as is consistent with safety. Any wasting, therefore, either internally or externally, tends to become serious much earlier than if thicker plates are in use. Internal corrosion is met with in many cases, reaching to a depth of $\frac{1}{8}$ inch on the shell plates and about $\frac{3}{16}$ inch on the chimney tube. As the shells in these cases are constructed of plates $\frac{1}{4}$ inch thick originally, it will be seen that the above wasting causes serious reduction in the margin of strength of the boiler. These boilers are usually carefully attended, and all parts which are accessible under ordinary conditions are generally in very good order. It is, however, to be regretted that many such boilers are quite unprovided with openings for the examination of the interior, and generally for internal inspection the boilers have to be entirely taken apart at the bolted joints provided.

Small vertical boilers of the ordinary types, such as are largely used by contractors and small steam users, are not economical steam producers, and are liable to defects of various kinds, leading generally to comparatively rapid deterioration. The small space they occupy, their portability and similar considerations, however, lead to their being largely used by parties who require small steam power, and also where handiness and convenience of application are a consideration, as in the case of contractors, or for steam cranes and similar objects. The conditions under which such boilers are used often involve attendance of a less efficient nature than is the case with larger boilers where the requirements of several boilers necessitate one attendant devoting the whole

of his time to that object. One of the most frequent causes of deterioration in vertical boilers is leakage at the mud-holes and bolted joints, this leakage causing continual moisture of the adjacent plates and reducing them very severely. To economise space, these boilers are sometimes fixed in the corners of buildings, leaving two sides of them inaccessible. In some cases accumulation of dirt or ashes takes place at the inaccessible parts, resulting in serious wasting; and considerable expense in repairs is also incurred simply by the practice of allowing damp ashes and coals to rest against the boiler, the plates beneath being kept in a state of continual moisture—the most favourable condition for the development of external corrosion. In the fire-boxes, serious wasting is frequently met with about the bar level, the reduction being usually uniform and continuous round the box at this part. This is a defect which has been responsible for many explosions, and it is therefore most important that every care should be taken to keep these parts clean and dry so as to prevent wasting of the description referred to. Another common cause of deterioration in the fire-box is leakage at the vertical seams, which may cause local wasting of the plates nearly through. This defect, although necessitating repairs, generally speaking, does not weaken the fire-box so seriously as the general reduction at the bar level referred to above. In vertical multitubular boilers, in which a number of smoke tubes connect the furnace crown to the shell crown, the unequal expansion which necessarily takes place results often in leakages at the joints of the tubes to the shell crown, frequently seriously grooving the crown plates round the tubes and in several instances wasting the crown to a dangerous extent.

Internally, vertical boilers of the ordinary type suffer very severely, owing to unequal expansion and to the over-heating of the chimney tube in the part which passes through the steam space. This overheating takes place to a greater or less extent in the course of ordinary working, and greatly accentuates the strains due to unequal expansion.

With corrosive waters the movement from the above cause often results in severe grooving at the base of the chimney tube.

A large number of these boilers are used on fishing boats for the purpose of providing steam for the steam winches used to raise the nets. These boilers are usually filled with fresh water on going to sea, and as this is evaporated the required feed is made up of salt water. Under these circumstances, very rapid internal corrosion usually ensues and, from the nature of this, it would appear that the priming which takes place, and the motion of the boat, result in the chimney tube and the shell and crown plates in the steam space being covered with a film of sea water when the boiler is at work. The annexed sketch illustrates wasting of the nature referred to (Fig. 26). In the sketch the full lines indicate the original thickness of the shell, and the black portion the plates as reduced by the wasting.

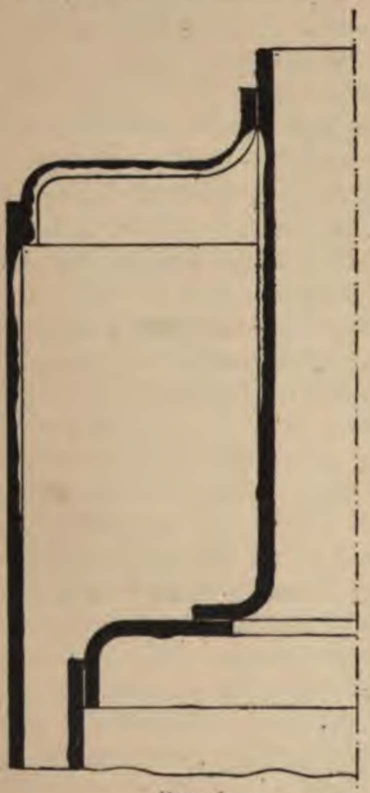


Fig. 26.

The most common repairs to vertical boilers are new fire-boxes, new flue-tubes and patches, or new plates at the lower part of the shell, and new cross tubes. The fire-boxes are very liable to burn at the zone A, in contact with the fuel, especially when this happens to be just above the base ring or seam, Figs. 27, 28 and 29, because the sediment invariably collects on the joint, causing overheating and corrosion. Cold feed water also settles

down to this zone, causing great variations of temperature. The fire-hole rings frequently give trouble as they restrict the freedom of expansion of the shell and fire-box, which are subject to great differences of temperature.

Cracks in plates are most frequent at bends, or radiating from rivet or tube holes. These cracks, when not near a rivet hole, may be prevented from extending by drilling a hole at the end of a crack, tapping it, and filling it with a copper rivet. When a crack leaks it must either be covered by a patch, riveted

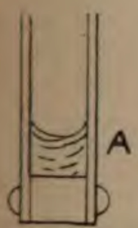


Fig. 27.

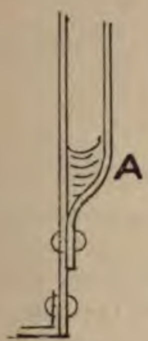


Fig. 28.

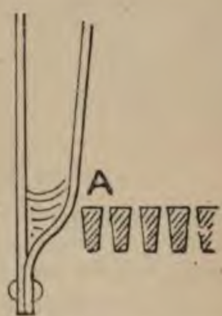


Fig. 29.

on or, if small, bored out, and the hole filled by a screwed plug; or a line of small holes drilled close together, copper rivets put in and well caulked so that their heads form a continuous line (Fig. 30). Sometimes a flat bar iron patch can be riveted on along the line of crack and well caulked (Fig. 31).

Laminated plates frequently bulge badly, and in such cases it is safest to put in a new plate, but the bulge may be reduced in some cases by heating it with a Bunsen burner and hammering it flat so as to admit of a patch being riveted over the spot.

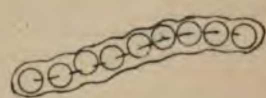


Fig. 30.

Repairs specially found necessary in Vertical Boilers.—When a vertical boiler stands on a recessed cast-iron plate, or even on a brick seating, leakage of any sort will quickly corrode the lower seam, as the water and dirt lie in constant

contact round the base. Such a boiler should be raised a couple of inches on four iron blocks to keep it dry.

Cross-tube boilers require frequent cleaning out of the cross-tubes as these are exposed to the hottest fire, and in some cases the lower tube is right in the fire and may soon fill with deposit and burn through. Where such a result

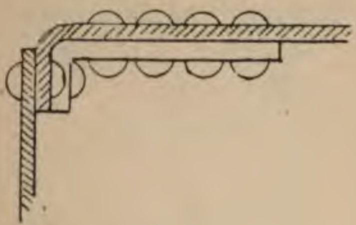


Fig. 31.

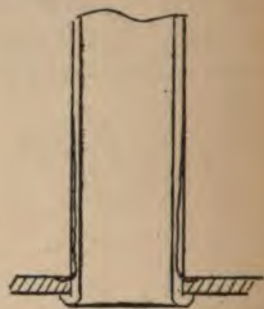


Fig. 32.

occurs it will be best to either lower the fire-grate or cut out the tube altogether and cover the holes in the fire-box with circular plates.

In the *multitubular types* the tubes are liable to burn through, especially at their lower ends where they often

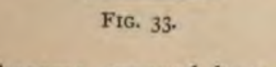


Fig. 33.

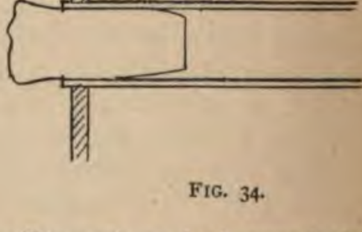


Fig. 34.

become grooved by corrosion (Fig. 32), or leak round the joint to the tube plate; in the latter case they should be expanded by a good tube-expander, and a new ferrule driven in (Fig. 33).

For temporarily repairing, or rather rendering useless a leaky tube, plugs of iron or brass may be driven in at each end,

Fig. 34; or a long bolt with two tapered plugs passed through and tightened up; or a smaller tube of the same length put through and expanded well at each end (Figs. 35 and 36). In cutting out old tubes care must be taken not to injure the holes in the tube plates; where these are corroded it is best to enlarge them with a fluted reamer and use a larger new tube.

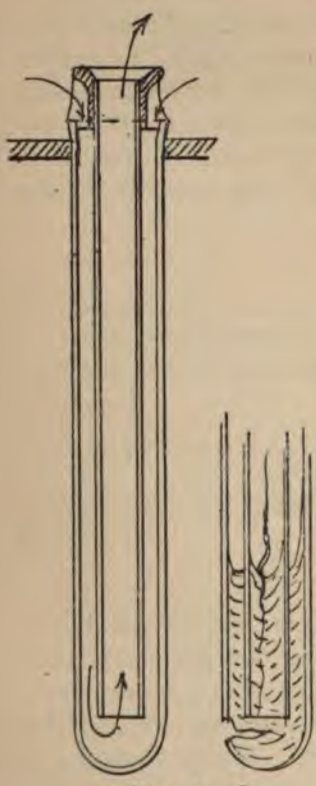
Field Boilers have suspended tubes closed at the lower ends, as Figs. 37 and 38, with an internal loose circulating tube; these inner tubes should be of brass or copper, but are frequently of iron and very thin, so that they often split up at the joints, causing the circulation to be "short-circuited," the result being that the bottom of the "Field" tube soon fills up with

FIGS. 35, 36.

deposit and burns through, sometimes leaking, but oftener without leaking at all; in fact, the end frequently burns entirely off (as in Fig. 38), the pressure being sustained by the deposit in the tube. Such tubes are easily replaced, which is one merit of this type of boiler, there being only one end to fit to the tube plate, the space above which is free from tubes except the central flue tube, so that, with a good sized man-hole, the tubes are easily accessible.

All vertical boilers should be set so that a man (not a lad merely) can get inside the fire-box, after removing the furnace bars, both to repair and inspect the interior, as the fire-box is the part of a boiler most liable to suffer, and needing most attention and proper inspection.

Water Tube Boilers.—Root's, Babcock and Willcocks',* Thornycroft's, Belleville's and others, formerly constructed usually with cast-iron pipes, are now commonly of wrought-iron lap-welded tubes, which are liable to burn out, crack or burst, or one or more of the numerous joints to give out. The water circulation in this type of boiler is stated to be very rapid, so that no amount of deposit is usually found in the tubes, each of which has its own cleaning cap at the end, and the lower ends discharge their sediment into a large cast-iron tube at the lowest part of the structure, from which it is blown out or cleaned out without difficulty.



FIGS. 37, 38.

The joints of the covers are simply planed true and bolted up by a bolt with faced head, no jointing material being used; the tubes are expanded into their joints, and can be drawn out when the cleaning cap is removed, to repair or replace.

Water tube boilers are now coming much to the front, the advantages claimed for them being, safety from explosion, economy of space—especially floor space, quick steaming, high working pressures, rapid circulation, adaptability to space and moderate cost in repairs. On the other side, the first cost is high, the brick-setting being a considerable item; and some types undoubtedly are trouble-

* A very large installation of water tube boilers of numerous types was exhibited at the World's Fair, Chicago, and well described in the *Engineer*, vol. 76.

some at the joints, besides which, from the small quantity of water they contain and large heating surface, they often fluctuate very quickly in pressure, and are therefore in particular cases difficult to regulate. But for marine purposes they seem to offer very important advantages in space and reduced weight, with also the possibility of using very high pressure safely. In the matter of economy there is little difference between them and the ordinary multitubular type. Another point in their favour is the large grate area available, and perhaps the accessibility of all parts.

The system of jointing them—formerly by various kinds of packing—now consists of rolled or expanded joints to all tube ends, and plain faced joints to covers; these, of course, require good workmanship, but when well made appear to be efficient; in other cases a thin asbestos washer is used with a ring of copper wire. The diameters of tubes vary from $2\frac{1}{2}$ to 5 inches, and the thicknesses corresponding to these from $\frac{3}{16}$ inch to $\frac{3}{8}$ inch, the thickest being those over the furnace; leaky or burst pipes can be easily plugged or cut out and replaced, and the new tubes are readily expanded into place also.

Water tube boilers are, however, not free from liability to explosion, though such accidents are neither so numerous nor so appalling as those of platework boilers. Out of twenty-two explosions recorded by M. R. Vincotte, eighteen consisted of longitudinal ruptures of tubes, most of them due to defective welding. Lap-welded tubes are generally used, butt-welding is quite unsuitable; and with lap welds a wider lap than is usual should be employed. The ends of the tubes are expanded into the end boxes and should also be beaded over to prevent drawing out.

Fittings.—Boiler cocks and fittings are short-lived as a rule. Those of the plug type are but little inferior to the mushroom valve; the hot water and steam, combined with deposit, soon cut and groove them both, so that they frequently require grinding in, reboring, &c., and are usually a constant source of trouble. Those of the plug type packed with asbestos round the plug seem to stand the best. Feed

check-valves are liable to stick fast by deposit settling on them when the boiler is standing, and can often be relieved by tapping the valve box with a hammer. Water gauge cocks and glasses also sometimes choke with deposit so as to give a false indication of the water level, especially after the boiler has been standing overnight, on Sunday, or at meal times. This deposit cannot always be blown out by opening the cocks, and it becomes necessary to unscrew the plugs and use a wire to clear them, after first letting the steam down to zero. Safety valves should have flat seats in all cases, and be kept well fitted; conical valves and seatings are liable to stick, and get cut more rapidly by the escaping steam. Blow-off cocks should be of brass in all cases and easily accessible. The plug type is almost invariably used; as the valve usually is at all times filled with mud and deposit, it is liable to stick hard unless opened and closed frequently. A very tight valve sometimes opens with great difficulty, and then cannot be shut again, causing danger of collapse of the boiler flues by emptying it before the cock can be closed. Fittings of all kinds cannot be too good, the best are decidedly the cheapest. Man-hole and mud-hole doors and bridges are now made of wrought iron or steel, the doors dished and curved by hydraulic pressure, the bolts have good collars and are riveted in. The plates of the shell in which these occur should be thicker than the others, to allow for reduced strength from the door-holes being cut in them.

Marine Boilers.—The old types of these, with large flat surfaces, are now obsolete, and the construction is reduced to the cylindrical form with flat ends, one, two or three furnace flues, and usually multitubular return flues; consequently, the general nature of the repairs does not differ materially from those of land boilers, though the circumstances under which they are executed may be greatly different. Leaky tubes and stays, sprung joints and seams constitute the most common defects to be repaired. The working pressure is commonly much higher than with land boilers; 150 to 180 lbs. being usual; consequently, with a large diameter the

shell plates are of great thickness, and the entire construction much heavier than with land boilers.

Forced draught is now often employed, especially on marine engine furnaces, to increase the output of steam without augmenting the capacity, and consequently the weight of the boilers. Numerous systems are in use, but it is fair to say they are scarcely out of the experimental stage as yet. The difficulties to be contended with are due to the increased and excessive temperature of combustion, and its consequent effects on the tube ends, angles of plates and all exposed points, as well as the trouble of burning out the fire-bars, &c. The heat is often localised and dependent on the firing. The

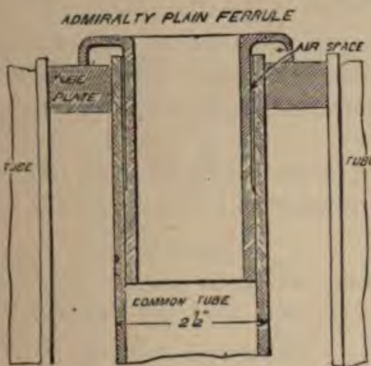


FIG. 39.

tube ends cause serious trouble very frequently by burning and leakage, and this has caused the introduction of various devices for protecting them, the most successful of which is a combined shield and ferrule (Fig. 39) lately invented by the Admiralty engineers, and used with great success in the boilers of the s.s.'s *Thunderer* and *Barracouta*.

A screwed ferrule has also been successfully used by Messrs. Humphrey, tapped into the tube end. It seems necessary that the tube ends be protected from the hot blast which of course impinges directly on them, the increased heat being carried away by the water too slowly to prevent burning.

It is questionable whether forced draught is a desirable innovation. It has rarely been used on land boilers, and is

entirely different in effects from induced draught. Experiments made by the Engineer to the United States Navy have proved that higher funnels will give all the draught necessary, and he has advised their use in the United States Navy in preference to any system of forced draught, and we are inclined to agree with him.

Forcing Steam Boilers.—A word may be said here on this very undesirable and expensive practice. A boiler will give good results when pressed up to its fair capacity, subject to good draught, cleaning and firing; but to obtain, say one-fourth more work out of it will require probably one-half more fuel, and from this point the economy falls very rapidly, the life of the boiler is greatly shortened, and the risks of accidental stoppages and cost of repairs much augmented. Many instances could be given where a new boiler could be paid for every year out of the excess cost of fuel under the forcing system.

The following tables will be found of service in connection with the foregoing notes on boilers and their faults.

TABLES OF DIMENSIONS, SCANTLINGS AND WEIGHTS OF VERTICAL, LOCOMOTIVE, CORNISH, LANCASHIRE AND MULTITUBULAR BOILERS.

Vertical Cross Tube Boilers.

Nominal Horse-power.	Diameter of Shell.		Height of Shell.		Diameter of Firebox.		Height of Firebox.		No. of Cross Tubes.	Diameter of Cross Tubes.	Diameter of Uptake.	Thickness of Shell (B Plates).	Thickness of Firebox (BBB Plates).	Thickness of Tubes & Uptake (BBB Plates).	Thickness of Crowns (B B Plates).	Approximate Weight.
	ft.	in.	ft.	in.	ft.	in.	ft.	in.		in.	in.	in.	in.	in.	in.	cwt.
1	2	0	4	0	1	8	2	1	1	4	4	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	7
2	2	6	5	0	2	2	2	6	1	5	5	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	11
3	2	6	6	0	2	2	3	4	2	6	6	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	13
4	2	9	6	6	2	3	3	4	2	7	7	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	17
5	3	0	7	0	2	6	4	0	2	7	7	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	20
6	3	3	7	6	2	9	4	3	3	7	8	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	25
8	3	6	8	6	3	0	4	9	4	8	9	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	30
10	4	0	9	0	3	6	5	3	4	8	9	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	37
12	4	0	11	0	3	6	6	6	4	9	10	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	45

Portable Boilers.

Nominal Horse-power.	Size across Front.		Width of Casing.		Height of Casing.		Length of Barrel.		Diameter of Barrel.		Number of Tubes.	Diameter of Tubes.	Thickness of Barrel (B Plates).	Thickness of Firebox (Low Moor Plate).	Thickness of Tube Plate (Low Moor Plate).	Thickness of Back Tube Plate (B B Plate).	Thickness of Shaped Plate (B B B Plate).	Thickness of Archplate (B Plate).	Approximate Weight.
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.		in.	in.	in.	in.	in.	in.	in.	cwt.
2	2	2	1	9	3	0	3	9	1	9	12	$2\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	16
4	2	7	1	11	3	7	4	6	2	2	18	$2\frac{1}{2}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	23
6	2	11	2	0	4	0	5	8	2	6	24	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	28
8	3	1	2	4	4	3	6	0	2	8	28	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	34
10	3	3	2	6	4	6	6	6	2	10	32	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	43
12	3	7	2	10	4	8	6	9	3	0	33	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{3}{8}$	50
15	3	9	3	0	5	0	7	0	3	3	40	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{3}{8}$	60
20	4	0	3	6	5	6	7	6	3	6	46	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{3}{8}$	70
25	4	3	4	0	6	0	8	0	3	9	52	$2\frac{3}{4}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	85
30	4	6	4	3	6	6	8	6	4	0	60	$2\frac{3}{4}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	92

Cornish Boilers.

Nominal Horse-power.	Heating Surface.	Diameter.		Length.		Diameter of Flue.		Diameter of Dome.		Height of Dome.		Thickness of Shell (B Plates).	Thickness of Flue (B Plates).	Thickness of Ends (B Plates).	Thickness of Dome (BBB Plates).	Approximate Weight.
	sq. ft.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	in.	in.	in.	in.	cwt.
2	24	2	9	6	0	1	3	1	0	1	0	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{16}$	18
4	36	3	3	7	0	1	6	1	2	1	3	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	25
5	47	3	9	8	0	2	0	1	3	1	6	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	29
6	65	4	3	10	0	2	2	1	6	1	9	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	40
8	82	4	6	13	0	2	2	1	9	1	9	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	54
10	96	4	6	14	0	2	2	1	9	2	0	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	60
12	112	4	8	15	0	2	4	2	0	2	0	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	66
14	126	4	10	16	6	2	5	2	0	2	0	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	72
16	141	5	0	18	0	2	6	2	0	2	3	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	84
18	161	5	2	19	6	2	8	2	0	2	3	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	96
20	178	5	4	21	0	2	9	2	3	2	6	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	120

Vertical Multitubular Boilers, with Ashpits formed in Base of Boiler.

Nominal Horse-power.	Diameter of Shell.		Height of Shell.		Diameter of Firebox.		Height of Firebox.		No. of Vertical Tubes.	Diameter of Vertical Tubes.	Thickness of Shell (B Quality of Plates).	Thickness of Firebox (BBB Plates).	Thickness of Crowns (BB Plates.)	Approximate Weight.
	ft.	in.	ft.	in.	ft.	in.	ft.	in.		in.	in.	in.	in.	cwt.
1	2	0	4	0	1	8	2	0	7	$2\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	7
2	2	6	5	0	2	2	2	6	12	$2\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	11
3	2	6	6	0	2	2	2	6	14	$2\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	13
4	2	9	6	6	2	4	2	9	16	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	17
5	3	0	7	0	2	6	3	0	18	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	20
6	3	3	7	6	2	9	3	0	20	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	26
8	3	6	8	6	3	0	3	3	25	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	33
10	4	0	9	0	3	6	4	0	30	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	38
12	4	0	11	0	3	6	4	0	30	$2\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	48
14	4	3	12	0	3	9	4	0	35	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	55
15	4	6	12	3	4	0	4	3	40	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	60
16	4	9	12	6	4	3	4	6	45	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	66
18	5	0	13	0	4	6	4	9	50	$2\frac{3}{4}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{3}{4}$	72
20	5	0	14	0	4	6	5	0	50	$2\frac{3}{4}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{3}{4}$	80

CHAPTER III.

BOILER COMPOSITIONS. FURNACES AND FEED HEATERS.

Boiler Coverings and Compositions.—The desirability of covering a boiler is beyond question on the score of economy, and if effectually done there should be very little waste of heat by radiation. There are several methods of doing this: covering them with brickwork is effective but rather clumsy. A thick layer of asbestos is very effective but should not be less than $2\frac{1}{2}$ inches thick, and is easily laid on wet, like mortar or cement. The Aston Chemical Co.'s permanent composition is recommended also. Hair felt covered with wood laggings is good, and has a better appearance than many other methods. It is much used for small boilers

where appearance is an object. Silicate cotton and slag wool are also recommended as good non-conductors—easily applied, and unchangeable by heat. Leroy's composition is also laid on like mortar, and has an established reputation of many years.

Boiler deposits consist of carbonate of lime, sulphate of lime, magnesic hydrate and silica. Carbonate of lime usually deposits as mud, but sulphate of lime, &c., form incrustations of various degrees of hardness.

Compositions for the prevention of incrustation are very numerous and more or less effective. In employing these, however, care must be taken that the substance used suits the chemical composition of the feed water, or failure will result. It can hardly be pretended by any manufacturer of these compositions that his particular cure will satisfy every case, and as a matter of fact, their indiscriminate use leads to frequent failures and wholesale condemnation of the thing as a fraud; we shall, therefore, not specify any of them, but recommend the reader to obtain a guarantee from the makers, after submitting a sample of the water for analysis.

The following treatment may, however, be adopted with safety. If the impurity consists almost entirely of carbonate of lime, it may be treated by Clark's process, which consists in the addition of caustic lime to the feed water, in the following proportions:—With 50 grains of carbonate of lime per gallon add 4 lbs. of caustic lime per 1000 gals. which will precipitate 8 lbs. of carbonate of lime per 1000 gals. in the precipitating tanks before entering the boiler. These tanks, therefore, require a capacity of at least 3000 gals. for an ordinary Lancashire boiler.

For eliminating combined carbonate and sulphate of lime in the feed water, use for each grain of sulphate of lime per gallon 1 oz. of caustic soda per 1000 gals., and for each grain of the carbonate of lime $1\frac{1}{2}$ oz. per 1000 gals., but only enough soda need be used for *one* of these two elements—that which requires the highest amount—as it will also serve to precipitate the other as well. This water can go direct to the boiler if required, and the caustic soda is *pure*; it then, of course,

deposits its precipitate in the boiler, and it must be blown off frequently.

In America we found that a mixture of graphite and cylinder oil was highly recommended, and very generally used.

Boiler Furnaces.—The repairs to furnaces generally are chiefly new fire-bars; less frequently new bearers; and still less frequently new dead-plates and fire-hole doors, or even furnace fronts. These matters involve no difficulties that need referring to here; but there are one or two matters of detail that must not be overlooked.

Fire-bars should be cast of hard white metal, not too brittle; No. 3, or "mottled" pig is suitable. Bars cast of ordinary foundry irons will generally burn out in a remarkably short time, besides which they warp, and the cinder clings more readily to them. The spacing and thickness of the bars are important, and depend on the class of fuel, as, in fact, the spacing really determines the proportion of air to fuel. For dust coal, slack or burgy, the spaces should not exceed $\frac{3}{8}$ inch. For lump coal, anthracite or coke, it may be as much as $\frac{3}{4}$ inch or $\frac{7}{8}$ inch. The narrower the spaces are the narrower should the bars be also. Care must be taken to allow for expansion, both in length and width.

Numerous forms of moving, rocking, rolling or tilting bars are used also; but a good stoker needs no such accessories, and can produce results equal to any if he understands his business.

Furnace doors should be protected by a baffle-plate, and if possible be provided with an adjustable air grating or ventilator, to regulate the admission of air over the fire.

Mechanical Stokers are simple pieces of ordinary mechanism that involve no special mention. The bearings, worms and other wearing parts are all that usually need repairs. They differ considerably in their methods of feeding the fuel, and invariably use coal dust, which they spread over the fire by scattering it in small quantities at intervals capable of regulation.

Boiler settings of brickwork, *flues and chimneys* are

attended to by bricklayers, usually men who have had experience in this class of work.

Economisers are, in fact, water tube boilers, excepting that they do not usually heat to the boiling point, so as to generate steam; but in construction and repair they are practically identical except that the tubes are vertical. Most of them have mechanical scrapers, driven from a donkey engine, to keep the tubes clean on the exterior.

For these it is necessary to have bye-pass flues, so that the stoker can pass the gases direct to the chimney in firing up in the morning, and after stoppages; or the draught will be destroyed by the cold pipes. The size of an economiser is usually calculated by the number of pipes, which are 4 inches diameter by $\frac{5}{16}$ inch metal, and 9 feet long. Four pipes are required for each ton of coal used per week. The temperature of gases ordinarily discharged from a boiler flue is nearly 600°, which, by using an economiser is reduced to 300°; but should not be further reduced, or the draught will be seriously impaired. The temperature of the feed—which should not be introduced quite cold—say at 100°—is usually raised to from 212° to 250°, and the economy gained from 10 to 15 per cent.

Feed-water Heaters.—There are several types of these; the simplest is a closed tank into which the exhaust steam is led from the engine, either on to the surface of the water in the tank or by a dip-pipe caused to pass through the water; the uncondensed steam being discharged by another pipe into the air (Fig. 40). In others a coil of pipe is placed in the tank and the steam led through it. Such feed tanks rapidly corrode at the bottom, from the hot water, combined with its active elements, and soon require new bottoms or new tanks. They are often noisy, from the steam hammering in the water, though this may be avoided by using a silent nozzle; but are also liable to cause some back pressure on the engine. Pressure heaters are of entirely different construction. In these the water is pumped through them to the boiler, so that they are always full of water, and at the existing boiler pressure. They throw down the greater part of the sediment from the water, and being liable to great variations of

temperature, corrode much more rapidly than the boilers they supply, and require frequent cleaning out. As may be expected the tubes do not last long. The mode of fitting these varies. In some a wrought-iron tube plate is used, and the tubes expanded in holes bored in the plate precisely as in a multitubular boiler; but in most heaters they are screwed into the cast-iron base, to which also the plate body is bolted. This latter should in all cases be capable of being lifted entirely off to expose the tubes for thorough cleaning or repair. Mud-holes are of little use, as the whole mass of tubes often becomes choked with scale and deposit. Weir's and Westinghouse's feed heaters for marine purposes, heat the feed water by injecting it in a spray amongst the steam as it enters from the exhaust. Fig. 41 shows the ordinary type of feed heaters. Similarly constructed heaters are in common use in hotels and large buildings for heating water for domestic uses, but are generally fitted with a coil of wrought-iron tubes, through which live steam is passed; in other respects they need precisely similar attention and repair as feed-water heaters or boilers (Fig. 42).

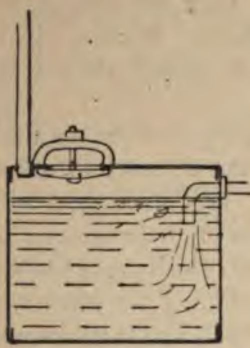


FIG. 40.

Boiler feeding is done by pumps, injectors and by gravitation. The latter is the easiest method where a sufficient head of pressure is available, and saves a lot of trouble with pumps and injectors, but water companies will not always allow a direct connection with a boiler, as, in case of the check valve failing, the hot water would run back into the mains. Feed pumps are generally attached to the engines driven from the boiler, but donkey or independent pumps are much preferred as they can be run or stopped at will. Pumps can also be driven by a belt from any convenient shaft, but if the shaft is not running of course the pump becomes useless, and difficulty may be experienced in filling the boiler when cold.

Injectors will feed with the boiler steam, and can be

obtained now to feed at very low pressures, and if kept in good order are simple and effective. They are, however, liable to be stopped by chips, grit and other obstructions, and at times are difficult to start. We therefore recommend in all cases that two independent feeding methods be always employed: a pump and an injector or two pumps, and that both be used in alternation to ensure their efficiency. See Chapter VI.

New "Lancashire" and "Cornish" boilers, by good makers, are invariably constructed with the feed valve and internal pipe fixed so that water is discharged above the level

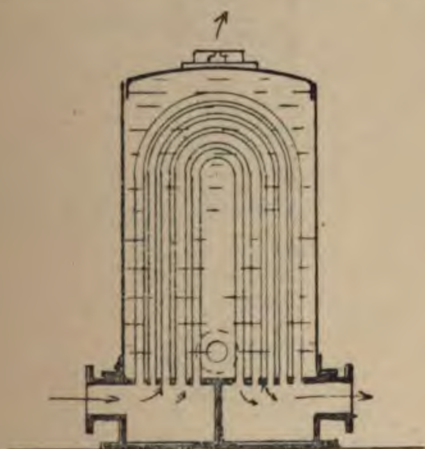


FIG. 41.

of the furnace crown, and in such cases it is impossible for the water to be backed through the pipe to a dangerous level. In many old boilers, however, the feed connection is either made at a low portion of the boiler, or the internal pipe is fixed so as to discharge the water at a low level, and in the case, therefore, of the back pressure valve failing, or where, in other instances, there is no back pressure vâlve, the water is liable to be forced back. In externally fired boilers it is especially necessary, in order to avoid the impact of a stream of cold water on the bottom plates, that the feed water should not be discharged at a low level. In internally fired boilers,

such as "Lancashire" or "Cornish" boilers, the internal feed pipe should be arranged to deliver two or three inches above the level of the furnace crowns; and where the feed water gives rise to incrustation, it is preferable that the internal pipe should be straight, so as to facilitate cleaning out, and provided with a plug for this purpose.

Domestic and Greenhouse Boilers.—Though not strictly engineer's work, a practical engineer is often called upon to deal with these, and with hot and cold water services in

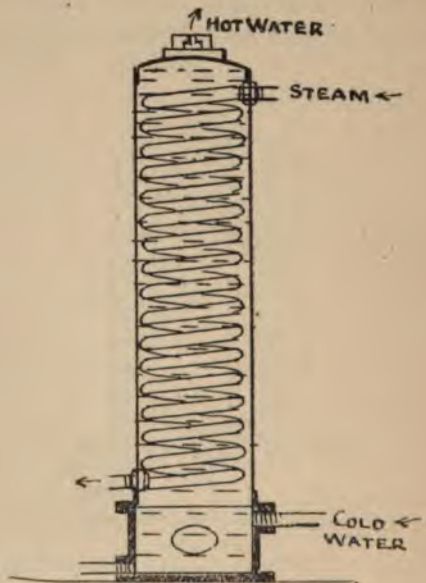


FIG. 42.

connection with them. Of domestic boilers the usual types are the common square or L range boilers, open or closed, generally of cast iron, but occasionally of wrought iron and welded, or wrought iron and riveted, shaped as Figs. 43 and 44 and modifications of them. The open boilers can be obtained from the makers of the ranges, otherwise there are so many different sizes in use that it is often necessary to obtain castings from the nearest foundry, where, as a rule, patterns can be made up to suit any size; and to facilitate

casting they may be cast with a loose top plate and the neck piece also loose, these being secured to the body by screws with a red lead joint, in which case the joints are not planed, but merely roughly fitted. To repair wrought-iron boilers is a comparatively easy matter, as they can be taken out, carried to the workshops, and the rivets, plugs, patches, &c., fitted with ease and certainty. (See p. 17.)

Greenhouse Boilers are of such an immense variety of forms that only such general repairs as are common to each type need be specified. The types chiefly in use, are the saddle boiler and its numerous variations, the vertical self-contained boiler, both of wrought-iron plate, and generally welded. Also the coil boiler and the vertical cylindrical boiler; the latter of same general construction as a vertical

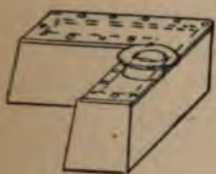


FIG. 43.

FIG. 44.

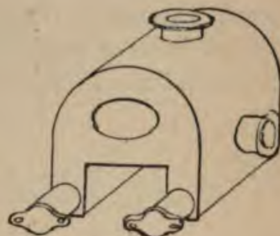


FIG. 45.

steam boiler (Fig. 22). In very many instances the deterioration of these boilers results more from neglect to empty them when not in use, neglecting to clean them out, feeding with bad water, leakages and bursting from frost, wet or damp situations, than reasonable wear and tear. Few of them are provided with any better means of clearing out the deposit than a small blow-off tap, which usually gets choked and useless, while if it is used it does little to clear deposit. Man and mud-hole doors are uncommon attachments, and when found are often so placed that only a part of the interior can be got at by their means. The best possible means of cleaning them out is to have two large pipes fitted, as in Fig. 45, at the lower front ends of the boiler, whatever its shape, and closed by planed covers jointed with asbestos, millboard or

grummets. The mud can easily be removed by a rake through these pipes. Small leaks can be repaired by copper screwed plugs, and if the substance of the plates is substantially uninjured, patches may be used on thin places with advantage, fixed by simple countersunk rivets or screws (Fig. 46). In worse cases the whole of a side may be cut out, leaving only a flange round to take the rivets, and

FIG. 46.

a new plate applied (Fig. 47). Coils generally require renewing entire, but occasionally crack at the weld or lap; these may be temporarily repaired by a wrought-iron clip, well fitted and bolted up tight (Fig. 48). Flue tubes when worn through, if not cut out and replaced by a new tube with ferrules or backnuts, may be plugged (if those remaining are sufficient to maintain the draught), or a smaller tube driven through and well expanded at the end. (See p. 26.)

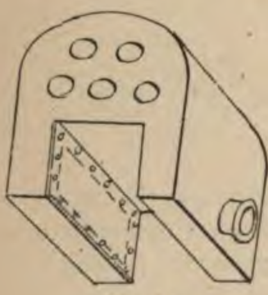


FIG. 47.

Pipe work in connection with heating boilers (see also Chapter XLIII). Though not quite within our province to deal with the design and arrangement of these, yet, as we are frequently called upon to remedy a defective plan or suggest an improvement, it will be desirable to know something of the principles of circulating systems and where they fail in practice. The faults, where such exist, will be found to originate in one or other of the following:—sluggish circulation, due to bad arrangement; too small a section of pipes; choking of some part of the system by deposit; air or steam collected at a point where it—in effect—divides the column of water into two parts; insufficient fall in the pipes, or the connections to boiler too nearly on the same level; defective directing valves:

Defects in arrangement.—It will frequently be found that some part of the upper or flow pipe has a dip at one or more parts of its run, or the cold water supply may have been taken into the flow instead of the return pipe, or into the circulating cistern, so that the in-flowing cold water mixes with the hot water supply. Its best position is an independent connection near to the boiler (Fig. 49). A heating coil or branch flow and return pipe, if carried to a much higher level than the rest of the system, will often take all the hot water, or nearly so, destroying the circulation of the remainder. As

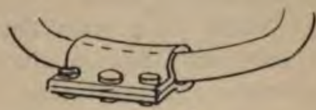


FIG. 48.

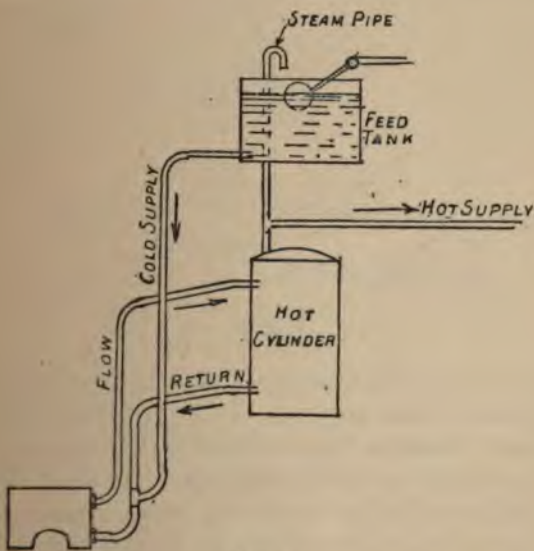


FIG. 49.

a general rule, where two or more separate services are required, they should each be taken, if possible, independently from the boiler, not branched out of one general service; and the conditions of each service should be approximated as far as possible by throttling the highest or most direct

either by a valve or by reducing the section of pipe. It must be borne in mind that the water takes the most direct course or the easiest by natural selection, and if one of the pipes is large enough it will select it to the entire neglect of the remaining ones.

Small pipes soon choke and corrode, and so stop the circulation. Square elbows, projections inside the pipes, shoulders, &c., all tend to obstruct the flow and gather deposit. An air pipe is necessary to take off air and steam from each of the highest points where it is possible for it to collect. Where the fall is insufficient from local causes, it may be remedied by giving the flow pipe a standing syphon, as Fig. 50, at a point as near the boiler as possible, with an air pipe at the top.

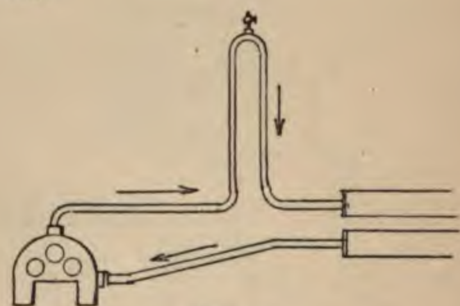


FIG. 50.

Expansion of pipes must be provided for either by expansion joints, if the pipes run a long distance in a straight line, or, where bends or branches exist, they separate the line of pipe into portions which can expand at right angles. A tap must be provided to empty the entire system, especially if there is any risk of exposure to frost; but in any case it is desirable to empty the pipes, &c., when out of use. The joints are best made with rust cement, but some patent cements are also employed, and patent rubber ring joints with special sockets to suit them are also used.

Boiler Cleaning—It has been pointed out that the amount and nature of deposit in a boiler depends on the quality of the feed water, the efficiency of the blowing off and the circula-

tion. It may further be modified greatly by the use of various ingredients, patent and otherwise, which, by altering the character of the deposit, prevents it, in some cases, from becoming a hard scale. Considering therefore that everything that enters a boiler—except pure water, and a very small amount of other substances vaporised during ebullition—remains there, the importance of regular and systematic cleaning will become evident. Further than this, it is well known that scale greatly reduces the efficiency of the heating surfaces by retarding the transmission of heat; forming, in fact, a bad conductor or blanket, which may reduce the steaming capacity—and hence increase the consumption of coal—from 10 to 40 per cent., besides introducing an

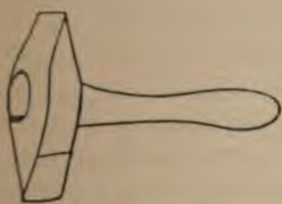


FIG. 51.

FIG. 52.

element of danger in the possible overheating, and thus burning or distortion of the plates.

Unfortunately comparatively few boilers are really accessible for thorough cleaning, and as a consequence this work gets neglected and put off, as such work always will, so long as it is made so extremely unpleasant as it is. It is often the job for the holidays, and left to the apprentices and lads, who detest it utterly. Any kind of a tool is used, as a rule, and the work can seldom be inspected by a competent man because he cannot get inside.

Proper sets of tools to reach every part ought to be made and kept handy, such as chipping hammers, scrapers, long handled tools shaped for the spaces round fire-boxes, between tubes &c., hand brushes and shovels to take up the scale (Figs. 51–53).

In cooling down, the contraction often loosens a good

deal of hard scale; otherwise it must be got off by hammering and scraping, and in some cases chipping by chisels. The edges of seams and round rivet heads are the most difficult to clean, but at the same time are the parts most needing it.

FIG. 53.

A good deal of mud in difficult spaces can be washed out by a hand pump and jet. Cross-tubes sometimes get entirely choked, and also the spaces between the tubes of multitubular boilers.

A careful examination should be made of the plates, &c., after cleaning, by a competent man, and any incipient defects remedied at once; delays in boiler repairs are extremely dangerous and costly.

Maintenance.—To maintain the efficiency of boilers generally, therefore involves such usage as will avoid or mitigate the causes of deterioration. Some of these are, of course, from their nature not avoidable by any usage, such as defects of manufacture or design, but careful stoking, frequent cleaning and examination, internally and externally, attention to quality and temperature of the feed water, as well as regular feeding, immediate attention to any defect that may appear, and lastly, avoidance of hard firing or forcing a boiler, are the principal points that need looking to to maintain its efficiency and length of active service. Thorough and regular inspection go far to prevent losses through faults unsuspected or overlooked.

Management of Boilers.—The following well considered instructions are issued by the National Boiler and General Insurance Co., Limited, of 22 St. Ann's Square, Manchester, and embody the most important points to be borne in mind in preserving and satisfactorily working boilers generally.

INSTRUCTIONS TO FIREMEN.

Water Level.—Keep the water in the boiler at a uniform level. Always test the water gauges before firing up in the morning or after stoppage, and frequently try them when boiler is at work. Every

cock must be used at each testing. If the glass gauges act slowly, clear out the passages with a piece of wire.

Feed Valves, Pumps, &c.—The feed valves, &c., should have constant attention, so that the water in the boiler may not run short. Where boilers are fed through an economiser, regulate the feed, if possible, on the *pump* side of the economiser, and when getting up steam in the morning see that the damper to bye flue is kept open until the engine is started.

Should the water fall too low and it cannot be immediately restored to the proper level, draw the fires at once; but if the furnace plates are already bared of water and becoming overheated when deficiency is discovered, it will be preferable to damp the fires by immediately throwing on ashes or other non-combustible matter and to close the dampers, as the act of drawing the fires might cause serious increase of heat.

Fusible Plugs.—Fusible plugs, like all other fittings, must be kept clean, the scale on water side and sooty deposit on surface exposed to the fire being well scraped off about once monthly. If the patent improved double-cone plugs, the cone should be changed at each stoppage of the boiler, the two cones supplied with each plug being used alternately. The fusible metal in these cones should be renewed at intervals not exceeding two years. This metal in plugs of other construction should be renewed more frequently, say once annually at least.

All low-water safeguards should be tested and examined each boiler cleaning time.

Blow-out Cocks, Valves, &c.—Be most careful to see that the blow-out cocks or valves are properly closed and not leaking after using them. Keep all valves and all other fittings in good and reliable order, and at stoppages take all of them to pieces for examination and cleaning.

Safety Valves.—Never attach extra weights to, nor alter the load on the safety valves; frequently test them carefully by hand, at least once daily, and see that they work freely and are not liable to stick in the seatings, &c.

Furnaces.—Keep the bars evenly covered with fuel and free from clinkers. Regulate the fires by dampers, and never leave the furnace doors wide open, or the riveted seams may be injured.

Boiler Cleaning and Inspection.—Keep the inside of boiler clean and free from deposit, or injury may result involving expensive

repairs. Sweep out the flues every three months at least; brush the soot, &c., off all the plates, and carefully examine the boiler in every part, especially where in contact with the brick seatings. A dirty boiler wastes fuel, whilst dangerous defects may be hidden and not be detected. Complete cleaning is of especial importance previous to thorough examination by an inspector, otherwise the inspection cannot be satisfactory and reliable.

The boiler should not be emptied under steam pressure, but the water should be allowed to remain in until the brickwork, &c., is all cooled down. The practice of emptying under steam pressure and filling up immediately with cold water is very objectionable, and frequently occasions serious fractures at transverse seams at bottom of boiler.

Never close a boiler after stoppage until the interior has been carefully examined, especially all openings, viz. *to the safety valves, feed pipe, water gauges* and other fittings, and see that each one is clear, and that everything is in safe working order.

Great care should be exercised in the use of boiler compositions, as many of them are of objectionable character, and merely add to the impurities contained in the water. Where compositions are used, use blow-out frequently.

Where feed water is heated by exhaust steam from an engine, the steam should not mix with the water, as it contains grease which, with the flour-like deposit found in some waters (especially from wells), often causes damage to furnace plates.

Externally Fired Boilers (see "Boiler Cleaning" above).—The seams over the furnace should be frequently examined; if any serious fracture or other defect be observed, the boiler should be stopped until all is made good.

On the Scope and Value of Thorough Examinations.—There is no doubt that experience has shown that thorough examinations greatly reduce the risk of explosion and of accident by enabling defects to be detected. Thorough examination in ordinary cases is understood to mean the inspection of both the interior and exterior of all plates, so far as the usual opening and cleaning of the flues and the interior will allow this to be done. Under normal conditions such examinations permit the parts—from the defective condition of which explosions arise—to be seen. Under

ıbnormal conditions, however, such as peculiar construction ɔf the boiler, bad setting, or excessive flue brickwork, the nspection mentioned above may not be sufficiently complete, and the question arises, to what further extent should the examination be carried? Thus, many boilers at collieries are unhoused and are covered by brickwork, and in other cases boilers are set on broad brickwork seatings, giving rise to unusual risk of external wasting. "Rastrick" and similar boilers, heated by furnace gases at iron-works, are subjected to unusual straining, and are liable to excessive deterioration about the bottom ends, owing to the great heat of the furnace gases which impinge on the plates. In the case of locomotive boilers, again, the construction of the boiler, under ordinary conditions, only allows of a very small portion being seen, the lagging on the outside of the shell preventing external inspection, and the tubes and internal stays preventing the boiler being entered and the parts being seen. In such cases as the above, more complete examinations are essential to safety. In iron-works boilers, the lower parts, on which the flames impinge, should be entirely bared at least annually. In the case of unhoused boilers, baring of the tops and the flue covering is certainly desirable at intervals of a few years, and more frequently if the covering be not arranged to prevent rain passing through, or if the flue covers do not drain the rain water properly away from the boiler plates. In boilers of the locomotive construction, it is well known that leakages under the lagging cannot be usually detected, and this should, therefore, be regularly removed at intervals of a few years. The regular removal of the tubes is also necessary. In some instances it may be necessary to do this annually, and the frequency of the withdrawal of tubes depends on the conditions under which the boiler is worked. With the further special precautions indicated above, and adapted to each type of boiler, and modified or extended according to the conditions of each case, the risk of explosion or serious accident arising from defects, may be still further reduced, but there still remain certain defects arising from the construction of the boiler, which cannot be detected in this way. Thus, some

explosions have arisen owing to fractures through the rivet holes on the inside of the lap, where the defect could not be seen either from the water or the fire side of the plates. Sometimes these defects extend through the plate and manifest themselves by leakage, or are visible to the eye, and are so detected before explosion occurs, but in a number of instances they would appear to have led to serious disasters. Probably most of these have originated owing to bad methods of construction. Thus, some inferior makers of boilers, even at the present time, are in the habit of completing the bending of their plates near the laps by hammering the edges over a set—a process which is extremely liable to cause local distress or fracture of the plate, and set up defects of the nature referred to. To reduce the risks described to a minimum, it would therefore appear that in the first instance it is desirable that the boiler should be carefully designed so that all parts may be of suitable strength and proportions, and arranged so as to permit of inspection in the ordinary course of work. The boiler should be well constructed of good material, and by a good maker, and should have careful attention in working.

A tendency exists to place undue reliance on the hydraulic test as a criterion of the safety of boilers, and this tendency appears to have been fostered and commended to steam users by the regard, in some instances, paid to the hydraulic test by the official utterances of the Board of Trade in the inquiries on boiler explosions. It is a plausible but unsound argument that if a boiler stands testing to a pressure much beyond that at which it is proposed to work, it may be considered safe. Our experience has, however, shown to us that in many instances it is liable to seriously mislead. For instance, many second-hand boilers are offered for sale on the basis of the fact that the boiler has stood a hydraulic test to a pressure much in excess of that to which it is proposed to work it and for which pressure careful inspection has proved that it is quite unsuitable. Boilers which are seriously defective frequently withstand hydraulic test to a much higher pressure than that at which they would fail if they were worked under

steam, and the reason for this apparent paradox would appear to be that the steady pressure under hydraulic test is quite different in its effect in setting up stress on a steam boiler from the conditions of ordinary work. Thus, when a steam boiler is being worked, some of the principal straining effects are due to the inequalities of temperature, and the varying expansion or contraction resulting. In some boilers the stresses set up in this way are sufficient to cause rupture and explosion, as for instance, the ring seam rips in long cylindrical externally-fired boilers, and in many other cases the movement causes severe grooving, as in the case of front ends of "Lancashire" boilers or the furnace crown plates of ordinary small vertical boilers. Further variations and stresses are also set up by the fluctuations of steam pressure from time to time. It is quite evident that the hydraulic test fails to verify, or otherwise, the strength of the boilers as regards these racking strains due to the varying temperature and pressure, and it is this fact mainly which constitutes the essential difference between the conditions of hydraulic tests and those existing in ordinary work, and, taking account of this great difference, the behaviour of a boiler under the hydraulic test cannot by itself be considered as a reliable guide as to its safety. It must, however, be admitted that in certain cases the hydraulic test, when judiciously applied, is a useful accessory, especially in the detection of leakages, as a test of the stiffness of flat surfaces, and in certain exceptional cases where the interior of the boiler is not accessible for any examination. The pressure, however, should be applied gradually and its effect on the form of the boiler carefully noted by measurements; if this is not done, permanent injury by distortion may result: the pressure applied in this way should never exceed $2\frac{1}{2}$ times the working pressure.

Chimneys and Flues.—The area and height of a chimney flue determine the draught of a boiler, and consequently limit its evaporative power. Assuming a rate of combustion required of 20 lbs. coal per square foot of grate per hour, the height should be from 90 to 100 feet for a single boiler, increasing to 150 feet for four or more boilers, and the area

1·5 times the area of the fire grate, divided by the square root of the height; or, when the actual fuel consumption is known, multiply the consumption in lbs. per square foot of grate by ·07, and divide by the square root of the height.

Exhaust steam should not be discharged into the boiler chimney unless the latter is unusually large, because the volume of steam chokes the flue and keeps back the gases, and also by wetting the brickwork absorbs heat in re-evaporating it, and thus also checks the draught.

Boiler flues in brickwork should always be large enough for a man to pass along easily. Large flues, instead of wasting the heat, as often supposed, conserve it by reducing the speed of the air current, thus keeping the gases longer in the flues, and of course longer in contact with the boiler; but independently of this large flues are necessary to enable the boiler to be inspected and the flues cleaned properly. The sectional area of flue may be one-eighth the area of the fire grate.

PROPORTIONS OF BOILERS PER INDICATED HORSE-POWER.

Type of boiler.	Area of fire grate.	Lbs. of water evaporated per hour.	Lbs. of coal consumed per hour.	Heating surface allowed.
	sq. ft.			sq. ft.
Egg-ended	·4	28	7	8
Cornish	·3	28	4	7
Lancashire	·25	28	4	7
Multitubular	·25	28	3½	5
Water tube	·25	28	4	5
Vertical cross tube	·35	28	5	10
Locomotive	·15	28	10	4
Marine	·15	28	2½	3

These dimensions assume that ordinary well constructed non-condensing engines are driven by the steam—excepting marine engines. When, however, more economical engines are employed, the power of the boiler will be increased and the dimensions may be proportionately reduced, the consumption of water being smaller.

Section II.—*PRIME MOVERS.*

CHAPTER IV.

STEAM ENGINES.

In following out our arrangements we will now deal with the motors in use for supplying power in the various industries and trades. They comprise steam engines, air engines, gas and petroleum engines, hot-air engines. Water motors comprise water-wheels, turbines and water pressure engines. Windmills. Electric motors are not within the province of the mechanical engineer.

Steam engines provide the engineer with a large proportion of his repairing work, not from inherent faults of design, but simply because they constitute so large a percentage of the motor machinery in use. Still there are defects of design in many cases to be discovered, and if possible, remedied. The mechanical efficiency of steam engines, that is, their $\frac{\text{Brake H.P}}{\text{Ind. H.P.}} = \cdot 85$ to $\cdot 94$, so that their internal friction ranges between 15 and 6 per cent.

We will subdivide the typical engine into its component parts and dissect them.

The Cylinder and Piston.—In horizontal engines these wear oval from the unbalanced weight of the piston and rod bearing on the bottom side; a long piston causes less of this wear than a short one. When this wear becomes excessive the cylinder requires reboring, which is best done in the lathe or boring machine, and of course as little metal as possible should be removed. A hand machine is sometimes used to

bore out a cylinder *in situ*, and though a slow job it can be done effectually. Fig. 54 shows such a machine, manufactured by Mr. W. Allchin, Northampton, which can be used for a considerable range of sizes of cylinders, is easily fixed, and

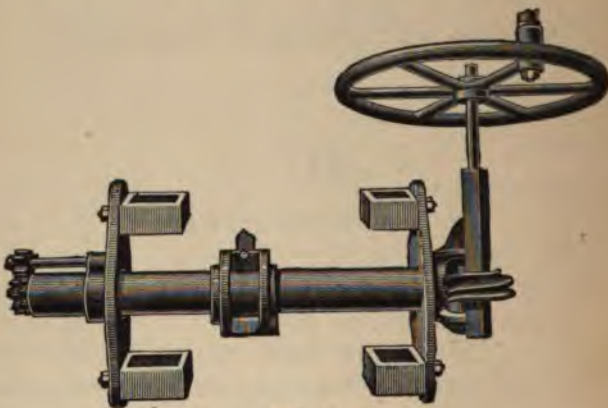


FIG. 54.

has a continuous feed to the boring tool, so that a smooth bore is obtained at one cut in less time than would be required to remove the cylinder from the engine.

In vertical engines the cylinders seldom wear out of truth;

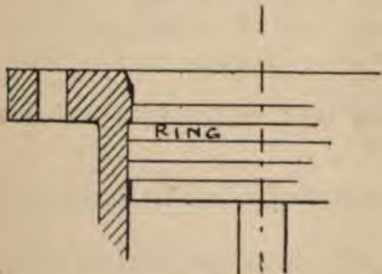


FIG. 55.

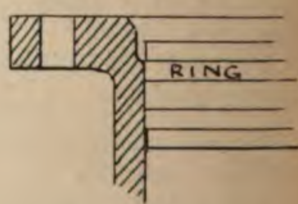
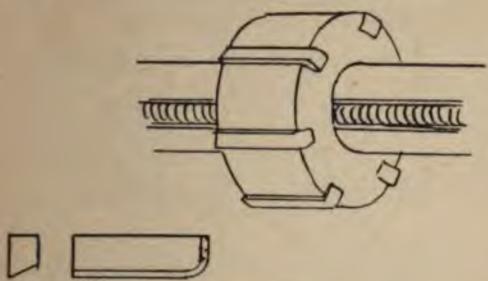


FIG. 56.

but in both vertical and horizontal engines a ridge or slight collar is often left at both ends of the bore, from the rings not clearing the parallel bore at the ends of stroke (Fig. 55); the reduced speed of the piston at these points adds to this

ndency, and in fact it will usually be found that the bore is rgest in the middle, where the speed of the piston is greatest nd the angle of the connecting rod causes the greatest pringing of the rod. When this ridge is slight it can be led and scraped off with a scraper of same shape as a 3-square aper file, from which in fact it is often made.

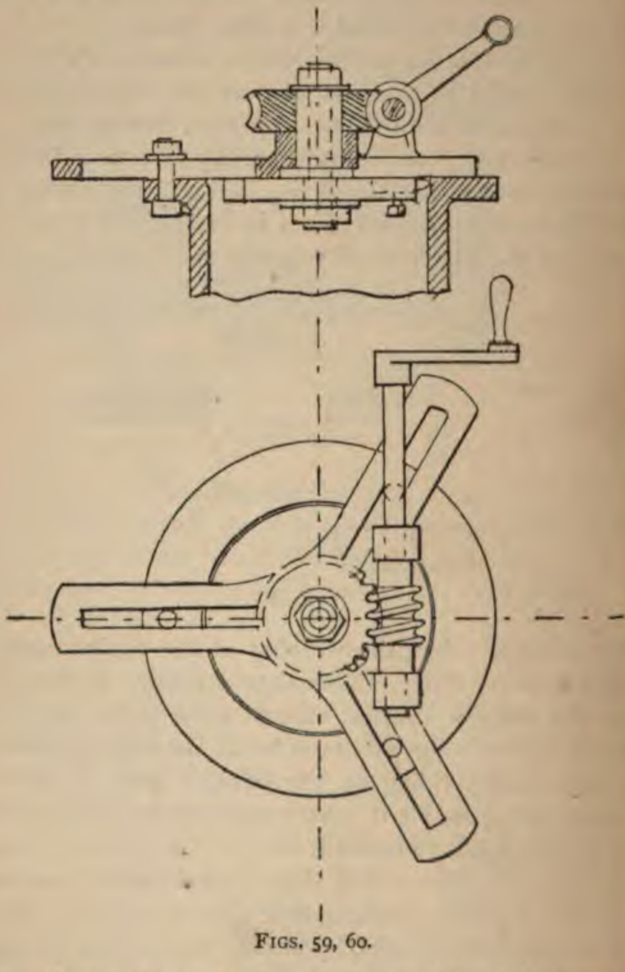
There is no particular difficulty in reboring a cylinder; a ough cut should be taken to remove the ridge at each end, s Fig. 56, and then a wood-packed boring head with hree cutters, well rounded, run through at a slow feed (Figs. 7 and 58); the greatest care required is in the setting of the ork. It is sometimes necessary to cut out the ridges left at he ends of the bore without reboring the cylinder as a tem-



FIGS. 57, 58.

orary measure, when the working of the engine cannot be topped even for a day. This should always be done when itting new rings in a piston, otherwise the piston may jam at ach end of the stroke, and even break the rings by their new nd sharp edges riding on the bevilled part of the ridge. Whenever it is possible it is very desirable not only to scrape lown the ridge but to recess it also, so that the rings clear the arallel bore a little, and a ridge then becomes impossible. This in fact becomes imperative if any alteration is made to he connecting rod brasses, by closing them up or fitting new nes, as then the piston does not stop at the same place at he ends of cylinder as before. New brasses by lengthening he rod reduce the clearance at the back end, and setting up ld brasses lengthens the rod and reduces the clearance at the

front end. It is possible to remove these ridges by han
tools, by chipping and scraping, but rather tedious. Figs. 5
and 60 show a boring apparatus for hand use that gives goo
results and is simple to make.



Figs. 59, 60.

It will sometimes be found that a blow-hole or spong
place exists in the bore of the cylinder, causing undue wear
the rings and even leakage past the piston. If the patch is n
large, bore a hole large enough to include it, and if possib

to some gas tapping size ; tap it, and turn and screw in a cast-iron or brass plug, the inner end of which may be shaped to suit the curve of the bore very nearly before being finally set and riveted up or pinned to prevent it turning, it can then be scraped true to the bore without much difficulty. Filling such holes from the inside is rarely successful, besides being dangerous, as the filling may fall out and jam the piston cr break the cover.

Cylinder with ports defective.—The ports may be too small altogether, so as to wire-draw the steam and prevent the engine developing as much power as is due to the boiler pressure and volume of steam available. Indicator cards from such an engine show that the piston runs away from the steam, as at A, with a badly defined cut-off (Fig. 61), and that the pressure in the cylinder never rises to that of the boiler. The port area should be such that the velocity of steam passing does not exceed 80 feet per second. The port area thus becomes

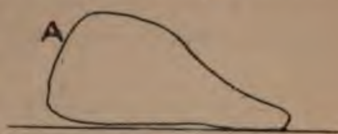


Fig. 61.

$$\text{Piston speed in feet per minute } \frac{\text{cyl. area sq. ins.}}{80 \times 60}.$$

There is no remedy for this fault but either a new cylinder or supplemental ports. It is possible in some cases to perform the latter operation by making a new valve face (and slide valve), bolted on to the old face, with larger ports in it, and run pipes or cast ports from these to each end of the cylinder. Where the cylinder is supplied by mushroom, Corliss or double-beat valves the difficulty is not so great, as these valves can generally be replaced by larger ones, have more lift given them, or the ports enlarged. Where the boiler is strong enough the pressure can be increased and thus the power of the engine augmented.

Cylinder ports have been occasionally found partly choked with foundry sand, not removed when the casting was dressed, or by part of the port core having floated off with the hot metal, leaving a constricted place in the port. If this cannot

be punched or chipped out by a chisel, bent to suit, the only remedy is boring into the port at the spot, chipping out the obstruction and plugging the hole made.

Another fault difficult to detect is where the steam port has a blow through into the exhaust from defective casting, so that at every stroke at that end of the cylinder steam goes direct to the exhaust ; it may even show on the diagram taken from that end of the cylinder, but more generally is not detected from the working of the engine. The port cores may have shifted in the mould so as to nearly touch one another, leaving a very thin partition of metal which soon gives way, when the blow through will very likely show at the exhaust pipe, and the boiler will begin to require an extraordinary amount of firing, often attributed to every cause but the right one. To remedy such a fault generally involves a new cylinder, but if the hole can be got at in any way it may be plugged or covered by a plate carefully let in by a good fitter. Instances will be met with where the piston nearly or quite closes the cylinder ports at the end of the stroke. Such ports should be cut into the cover or the piston bevelled off to admit the steam (Fig. 62).

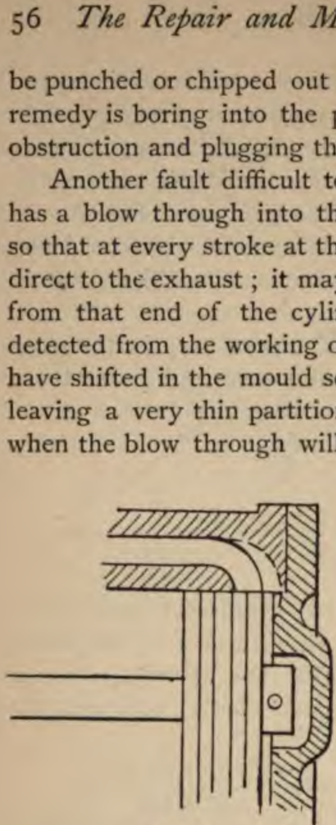
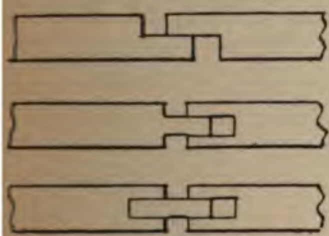


FIG. 62.

The Piston and Rings.—There are a good many types of these, with various methods of springing them outwards to fit the cylinder, and in fact rings can have too much as well as too little spring. The pressure outwards should never exceed the steam pressure, calculated on the area of the periphery of the ring, and in practice one-half this is nearer the amount required. Too much spring causes rapid wear both of the rings and the cylinder ; too little causes leakage past the piston. In fitting new rings to an old piston and cylinder it is generally necessary to turn up the grooves afresh, or where a junk ring exists, face its inner side and the

piston groove or rebate, after which the rings can be turned to a good fit. The best forms of split joints are shown in Figs. 63, 64 and 65. New rings as they come from the lathe seldom fit an old bore accurately, because it is rarely circular, and they should be fitted to the bore by filing and scraping before putting them in the piston ; they should also be marked so that if taken out they can be replaced in the same position. Simple cast-iron, brass or steel spring rings are very largely used for small engines, and wear fairly well until they become wide open at the joint and lose their elasticity, when they can be cheaply replaced by new ones. The ordinary steel "Ramsbottom" rings can be purchased, and are usually kept



FIGS. 63, 64, 65.

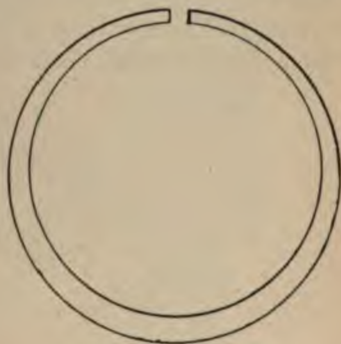


FIG. 66.

in stock in every engineer's stores ; the others can be made by any good turner. They should always be left thicker at the side opposite the joint and turned a little larger than the bore, so that when cut they have sufficient spring in them to fit tightly in the cylinder (Fig. 66).

Valves and Valve Boxes.—Slide vales and their faces will always pay for keeping in first class order by economy of steam. They are frequently allowed to run until the valve and face are a series of waves like Fig. 67. The steam lost by direct leakage into the exhaust will then be probably equal to that used in the engine. There are many types of slide valves, and those which are short in the dimension A, or have the rod pitched rather high from the face, soon begin to rock

and wear to a variety of curves, the alternate thrust and pull of the rod never being in line with the frictional resistance, i.e. the valve face. Cut-off valves and double-D valves are liable to this, especially if the lubrication is indifferent. Many cylinders have no means of lubricating the slide valves at all. Worn valves and faces of course require planing and scraping, and some amount of ingenuity is often required to fit up a rig, when, as is often necessary, the valve face must be planed *in situ.* When the box can be taken off this is comparatively easy; but when the box is cast with the cylinder, and in some cases even only the end cover is removable, as in portable engines and locomotives with inside cylinders, it becomes a troublesome job, necessitating a hand shaping machine with a special tool arm or holder, fixed on an angle plate bolted to the cylinder flange. The metal removed from the valve and

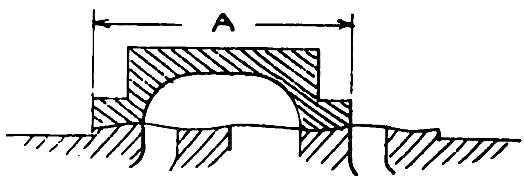


FIG. 67.

face has the effect of increasing the height of the valve spindle from the face, which, in those cases where the spindle passes through the valve, may necessitate easing the hole on the top side to allow the valve to seat properly.

Fig. 68 shows a very useful machine, manufactured by Mr. W. Allchin of Northampton, for planing these valve seats by hand without removing the cylinder from the engine, and will plane the valve-face of a 14 H.P. engine in three hours, requiring no filing or scraping afterwards. Sometimes it is possible also to fit up a hand planing machine of the ordinary make for the job by the exercise of some little ingenuity in fixing it.

Piston valves being cylindrical, when worn require re-boring, and should always have liners which can be taken out for this purpose, as in Fig. 69; it is then an easy matter to

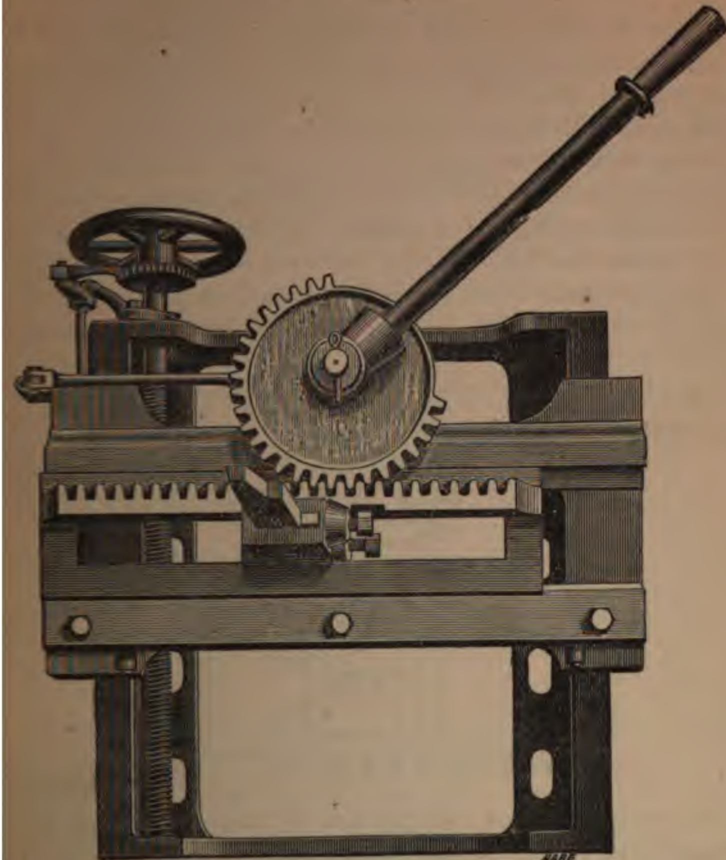


FIG. 68.

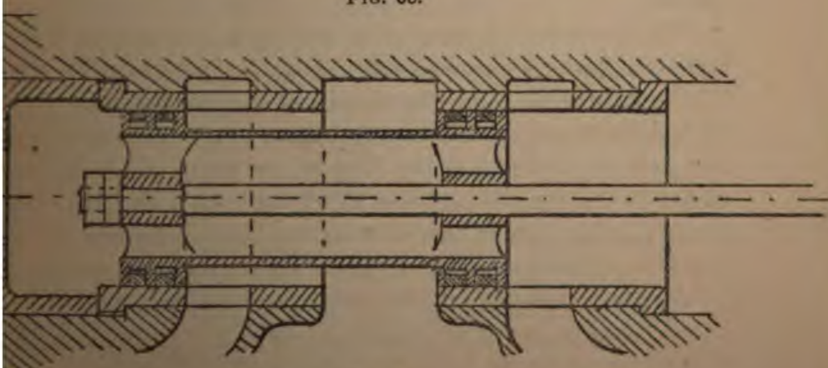


FIG. 69.

re-bore the liner and turn up the valve if it will admit of it; but if the wear is much, either a new liner or valve becomes necessary. As a rule they last as long as the cylinders; but not so the valve rings; these require pretty frequent renewal owing to their running across the ports; in fact this is a fault that has greatly hindered the employment of piston valves for large engines in place of slides.

Balanced Slide Valves.—There are many types of these, which are more or less partially balanced by packing rings on the back and similar devices, and considering the enormous

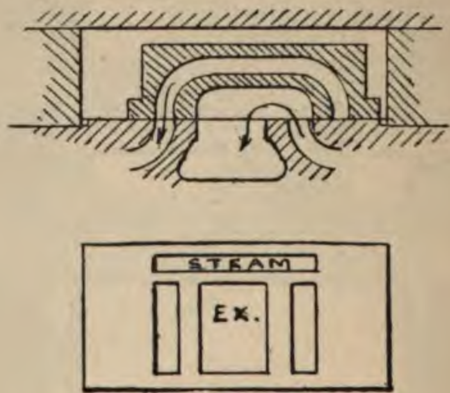


FIG. 70.

load on large valves, and the loss of power by moving them against this load, some reliable balanced valve is greatly needed.

Fig. 70 shows an interesting and ingenious method lately introduced, which seems to offer a fair solution of the difficulty. The steam enters under the valve and not into the box except by leakage under the valve; this leakage only suffices to raise the pressure of steam in the box to the point where it overcomes the balance of pressure under the valve, and therefore keeps the valve on its seat without any excess of pressure. It is therefore self-balanced, and quite automatic in adjustment.*

Piston and Valve Rods.—These wear considerably from

* T. W. Barber's patent, manufactured by Messrs Dick, Kerr & Co., Kilmarnock.

the friction of stuffing boxes, and become grooved and reduced in diameter; such rods, if still strong enough, are "skimmed up" in the lathe, that is, turned true again and polished, and the glands and necks bushed with gun-metal to allow for the reduced diameter of the rods. The quality and nature of the packing has a great deal to do with the wear of rods. It is greater in vertical engines than horizontal, because the leakage of condensed water runs down the rods, washes out all the lubricant and causes the rod to corrode and heat, soon destroying the packing also. Valve rods frequently wear very badly and this is found to be due to absence of an external guide and want of proper lubrication. An external guide keeps the rod working in a straight line, and reduces the wear in the stuffing box.

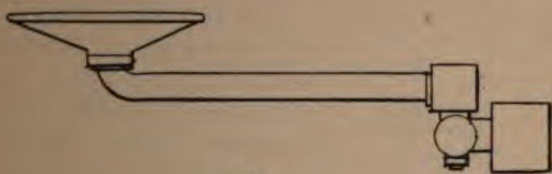


FIG. 71.

Draining and Drain Cocks.—A troublesome defect of all vertical engines with overhead cylinders is the difficulty of draining the constant drip from the piston and valve rods, and preventing it scouring the lubricant from the journals and joints below it. The trouble is often of so marked a character as to cause frequent repairs, new brasses, new pins, &c., and heating of crank pins and shaft journals, requiring an abnormal amount of lubrication and attention. Various plans are adopted for catching the drip in pans and other contrivances provided with drain pipes, and these precautions are worthy of attention, and will well repay their cost. Fig. 71 is a useful one.

In the horizontal engine this trouble does not exist, the water nearly all settles on the lower side of the cylinder, and is drained off by the drain cocks. Vertical engines, with the cylinder below, are also free from this fault, except that the small quantity of water which is carried up by the piston rod

generally runs down into the cylinder cover, and down to the base plate; but a channelled gland (Fig. 72) effectually remedies this fault; in fact, old glands can generally be turned to this form and fitted with a drain pipe.

Some boilers prime very badly, and unless a steam separator is employed or some method of superheating, a serious loss of water takes place, besides constant risk of damaging the engine from excessively wet steam, and the difficulty of effectually draining the cylinder. Steam pipes should always be fixed with a fall towards the boiler, not towards the engine, as in the latter case the condensed water runs into the engine with the steam, and where this is found to be the case it is highly desirable to alter it.

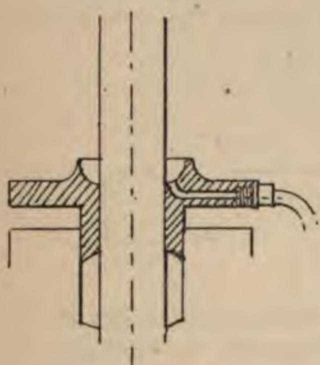
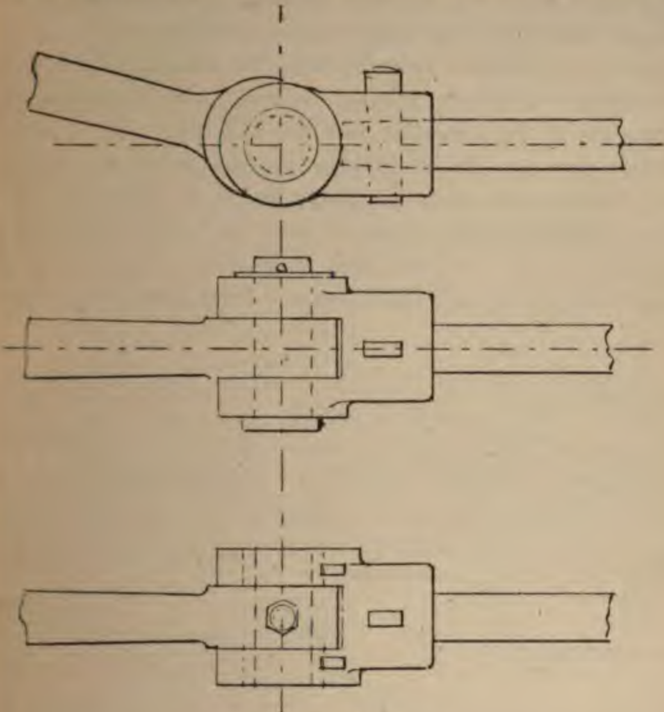


FIG. 72.

Cross-heads and Guides.—There are several types of these, but with the principal details in common. The piston rod is generally coned slightly at the end, fitted to a tapered hole in the cross-head and secured by a cotter; in other cases it is carried right through and fastened by lock nuts. It is very rare that anything goes wrong with these attachments if well fitted at first. The cross-head is hinged to the connecting rod by a pin, the rod being sometimes forked and sometimes single-ended; in the latter case the cross-head is forked, and here we frequently find defective designing. The pin should in all cases revolve in the fork and be fixed in the single joint, but is often put in loose and allowed to turn as it likes; it therefore takes the easiest method and revolves in the single end, and thus wears unduly, because the area of the bearing in the single end is less than in the forked end. Figs. 73 and 74 show the common design with the brasses in the connecting rod end; this would be much better if made as Fig. 75, with the pin secured by a set screw or cotter and the brasses in the cross-head.

These bearings are usually fitted with brasses, and the ost common repairs needed are new brasses, or the old es set up, and sometimes, but less frequently, new pins.



FIGS. 73, 74, 75.

iese latter wear as Fig. 76. They should be of steel and se hardened. A worn pin cannot be turned down smaller cause this would necessitate bushing the cross-head as well

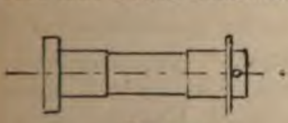


FIG. 76.

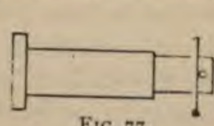


FIG. 77.

new brasses, and thus a new pin would be cheaper and npler; but if the pin is made of two diameters, as Fig. 77, it n then be turned down in the centre part when worn. The

method of setting up the brasses is often defective, difficult to get at, and results in neglect, and the same may be said in some cases of the means of lubrication; in fact, it may be accepted as a general principle that all parts of an engine or machine difficult of access will suffer from neglect.

It is important to bear in mind that the position of the connecting rod brasses determines and varies the position of the piston in the cylinder (see p. 53), and may have the effect of reducing or destroying the clearance at one end even to the extent of causing the piston to strike the cover, and in a cylinder that is much worn in the bore the piston may jam on the unworn end part of the bore as a consequence of setting up the brasses. Provision should there-

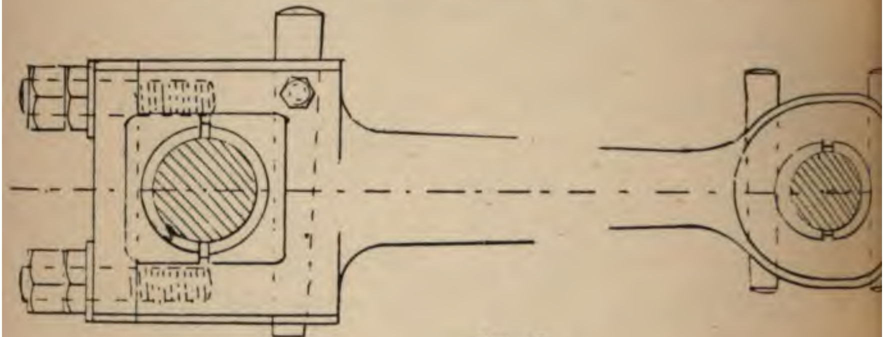


FIG. 78.

fore always be made that either the two pairs of brasses be set up opposite ways so as to neutralise one another's wear, or that each pair be set up from both sides so as to maintain the distance between the centres without alteration. Where no such provision exists resort is had to pieces of packing, formed of thin iron or brass plate, placed under the brasses. This is a doubtful expedient at the best, the brasses almost invariably become loose, and "knocking" follows; besides which, the regulation of the thickness of the packing is all guesswork. The ideal connecting rod should be constructed as Fig. 78, where the brasses must always be set up to the dead centres both ways as they wear, and thus the original distance between the centres remain unaltered.

Guides are either of the block, slipper or cross-head types, Figs. 79, 80, 81.

The wear of blocks and their guide bars is taken up by adjusting the distance pieces between the guide bars. This is commonly also a one-sided adjustment, all the wear going to the lower side because the lower bar has generally no

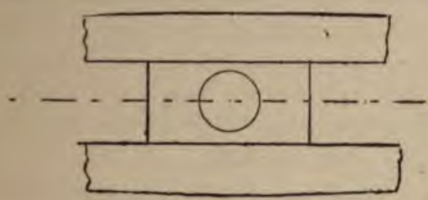


FIG. 79.

separate adjustment: thus the centre line does not remain true with the cylinder. Besides this, it is important to note that when the engine runs the usual and orthodox, or "outboard" way, as per diagram, Fig. 82, all the wear is on the lower bar, while if the reverse, it is on the top bar, and the adjustments should be made and provided for accordingly.

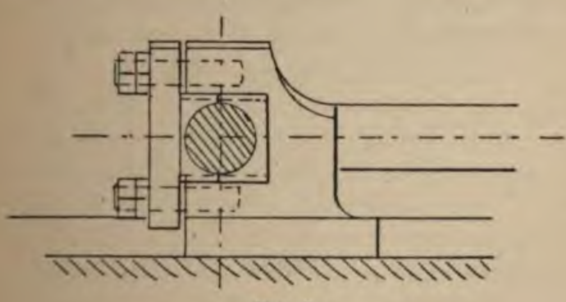


FIG. 80.

With the slipper type the "outboard" way is the best, as then all the wear and pressure is on the base of the slipper. In this type the guide strips, being usually of the V lathe-bed form, admit of easy and simple adjustment for wear. There are many modifications of this, but none more satisfactory.

Cross-head guides are sometimes run on flat guide bars,

planed and recessed to retain the oil, but more usually are circular, the guide "trunk" being then bored out with the cylinder at the same setting. This ensures true running, and should the crank happen to be slightly out of square the cross-head is free to twist slightly to correspond with the crank motion. But the adjustments for wear are more difficult to deal with in this type. Gun-metal shoes, with either screw

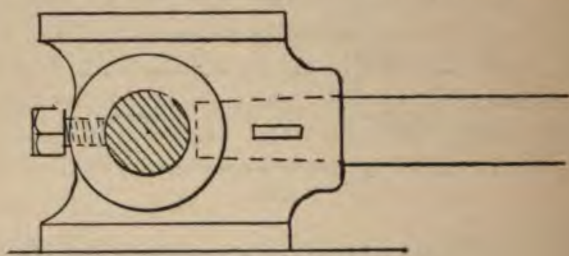


FIG. 81.

or wedge adjustments, are most frequently employed. With such the repairs simply involve new shoes, which should be fitted to the cross-head before being turned on it. Guide bars and guide trunks, like steam cylinders, generally wear hollow, that is, more in the middle than at the ends, and this is more pronounced in the guides than in the cylinder

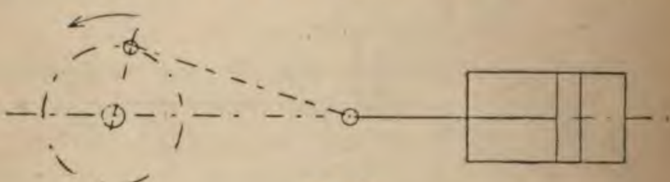


FIG. 82.

because of the varying angle of the connecting rod, so that in fitting new guide shoes, slippers or blocks, the condition of the guides has to be taken into account, as they may require replaning or reboring as the case may be.

Stuffing Boxes and Packing.—If the piston rod and cross-head of an engine are running true, there should be no wear on the gland, and therefore if we find a gland wearing oval we

may be certain there is a deal of play in the cross-head. Glands are very frequently bored out and bushed when worn, the only advice needed in connection with which is, to drive your bush in from the packing end of the gland so that it cannot draw out with the working of the rod.

The class of packing used varies greatly, and every driver has his own views on this question; but generally it may be said that the best kinds of packing for glands are those which are most soft and elastic, and they should be frequently renewed, because the heat and pressure soon destroy both softness and elasticity. Chalk packing is not of much use where there is a considerable run of condensed water from the gland. The more harsh the fibre the greater the scoring effect on the rod. A good depth of stuffing box is desirable, because in this way a more elastic and less pervious bed of packing is obtained without necessitating hard screwing up. Packing with rubber core is good as long as the rubber keeps its elasticity, but the dry heat soon destroys it. Metallic packings are now coming into use in the larger sizes of engines, and if applied when the rods are new will give much better results than fibre packings, and must be regularly lubricated, but their cost precludes their use in ordinary engines. Asbestos, unless of first class quality, is too gritty a fibre, as may easily be seen by cutting it with a sharp knife, which it blunts almost instantly; though it stands heat well it is deficient in elasticity. Hemp is too coarse. Cotton is soft and elastic but will not stand the heat. Flax and jute are better fibres for general use. Rubber cored packings are perhaps most effective on the whole, if renewed often enough; this is necessary, as the rubber soon hardens with the heat and oil; and, in fact, in spite of the great variety of packings on the market, patent and otherwise, there is still to be found a better one for general use. The packing is cut neatly to form complete rings, which are packed by a wooden driver with a blunt end; the bottom rings should be pressed down the hardest, because the pressure of the gland only tightens the upper rings.

Making Joints.—There are many ways of making steam

joints now in use besides the time-honoured red lead putty method. Each plan has its special advantages, and every vendor of patent jointing materials can support his particular material by the best of arguments. We will give the best known methods in detail.

1. The Red Lead joint is only effective if well done. The putty is composed of equal parts of red and white lead well incorporated on a slab, using a little linseed oil till it is of the consistence of dough or ordinary soft glaziers' putty ; if used too soft or badly mixed it is apt to blow out. A few threads of hemp or cotton are generally laid round the joint embedded in the putty, and the joint screwed up by degrees all round. The objections to red lead are these : it is "messy," it squeezes out of the joint into the bore of cylinders, pipes, &c., and often chokes drain cocks, valves, &c. ; it is a difficult joint to break again when needed, requiring the use of steel wedges, and sometimes endangering the covers or flanges of a cylinder or pipe.

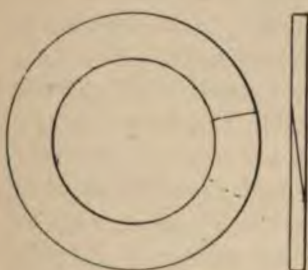


FIG. 83.

2. Rubber insertion. This is simple and effectual ; for planed joints the thinnest should be used ; for rougher joints use thicker material, according to the unevenness of the faces. The cheaper qualities are quite as effectual as the more expensive ones. It is not nearly as difficult to re-open an insertion joint as a red lead one, and of course in both cases the material cannot be used again. It is best not to cut a ring of insertion to get it over a rod or other central obstruction, but this may be done if the cut is made diagonally, as Fig. 83, so as to scarf the joint.

3. Asbestos joints. The material for these is made either as millboard or canvas, besides which complete rings are made and stocked by the makers, of various diameters and thicknesses, some with fine wire woven in them. It is claimed that these can be used more than once. For all

planed joints it is desirable, and in fact imperative, to make them as thin as possible, to avoid the chance of throwing the work out of line by screwing the joints up unevenly.

4. Paper or millboard joints. With good planed surfaces, free from corrosion and clean, these are easily made and very effective. Thick brown paper, thick soft packing paper, or thin millboard or strawboard are suitable. After cutting out soak them in oil, or paint both sides with red lead paint and screw up evenly.

5. Tarred yarn, laid in an even flat spiral round a joint without crossing itself anywhere, makes a good joint also.

Valve Gear.—Numerous varieties are now in common use, and new designs frequently introduced having various claims to increased efficiency and handiness. As a general rule the fewer joints in a valve gear the better, from the point of view of economy in repairs; the wear and tear of eccentrics and straps have led to the use of such gears as employ either the motion of the connecting rod or only one eccentric. It is not necessary here to give details of the numerous types in use, as these can be found in several well known volumes,* as we have simply to deal with repairing and maintenance. They all consist of plain and forked rods or links, centres, eccentrics and straps, slot links of various forms, link blocks, &c. The wear on the various centres is dependent on the strain they are subject to, and the angular oscillation of the rod or centre. All centre pins should be of steel and case hardened, and it is usual to case harden the rod ends, or else bush the eyes with hard steel; of course in large engines brasses and cotters will be employed. Worn pins and holes are the common weaknesses; the pins generally require renewing and the holes should be bored out with a fine cut rose bit, the pin being carefully turned to fit the finished hole, and then both are hardened. A good fit at first saves a deal of wear.

Tapered adjustable pins and centres can be introduced, as Fig. 84, and with an intelligent driver will save a lot of rattle and looseness. Another method is the double cone adjust-

* See 'The Engineer's Sketch Book.'

ment, Fig. 85; these are useful details in all cases of rattling centre pins.

Slot links and guide blocks when first fitted should have been hardened, for as a rule no provision is made for taking up wear. When a block becomes very loose it is usually replaced by a new one, but a good wearing job can be made by planing out one face, as Fig. 86, and running it with white metal; it can then be refitted to the link slot after the latter has been trued up parallel by file and scraper.

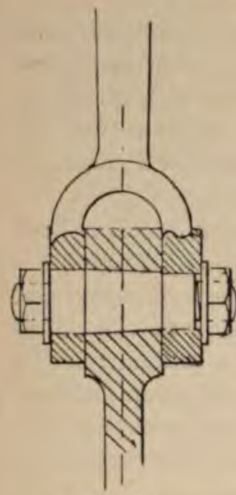


FIG. 84.

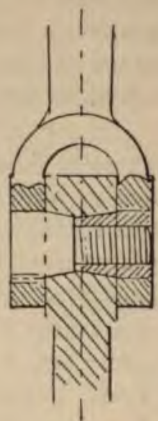


FIG. 85.

A loose jointed valve gear becomes a perfect rattletrap, and is a constant source of trouble and annoyance, besides having the effect of shortening the travel of the valves.

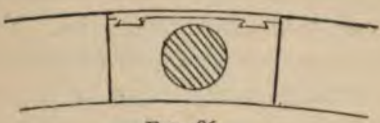
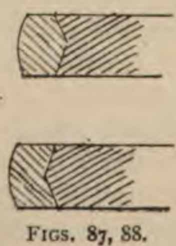
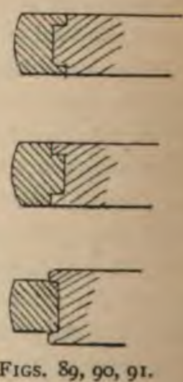


FIG. 86.



FIGS. 87, 88.



FIGS. 89, 90, 91.

Eccentric straps and sheaves, from their comparatively large diameter, wear badly. The straps are split in two parts,

joined by bolts or studs and nuts, and the best adjustment for them is a wood or hard leather packing between the joints, which are screwed up fairly tight, and the bolts lock-nutted; the packing will compress a little to admit of taking up the wear of the strap, and when this becomes too great the packing can be thinned down or a thinner one substituted. Lubrication of eccentrics is important, as in cases where this is neglected or it is liable to be washed out with the hot drip from the cylinder, the straps frequently run dry and "seize," causing breakage of the rod if nothing worse. For this reason the sections of straps, Figs. 87 and 88, are worse

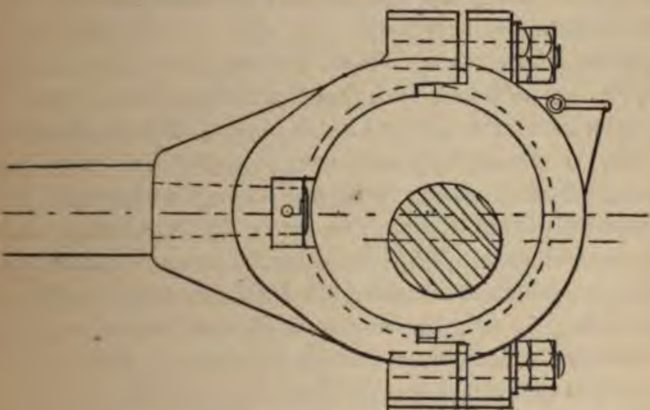


FIG. 92.

than Figs. 89, 90 and 91. Brass straps are frequently too slightly made to maintain their shape rigidly, and will sometimes break from crystallisation, due to constant springing of the metal by alternate reversal of the strains in revolving. There seems no reason why a similar method of adjustment to that of the connecting rod should not be used for eccentric straps, as Fig. 92, as it possesses equal advantages, and with a section as Fig. 93 (where a brass or white metal liner is shown, renewable when worn) will be found effective.

One important point very often overlooked is the proper guiding of the valve rods. Many engines have no guides at all, consequently the weight and the angular cross strain of

the rod causes rapid wear on the valve rod and gland, and makes it extremely difficult to keep the gland tight. In others a plain round eye is fixed for a guide: this, for want of sufficient area of bearing, soon wears oval also. The best guide is a square bar, larger in diameter than the rod and sliding in a pair of brasses having separate adjustments, or a round rod with similar adjustable guide brasses fixed to adjust in the same direction as the plane of the valve gear. It is a good plan to extend the valve spindle through the back end of the box in a bottle gland guide; this plan better ensures a true linear motion to the valve than the ordinary way.

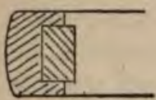


FIG. 93.

Corliss Valve Gear, Trip Motions, &c.—These are all more or less afflicted with the "rattletrap fever"; that is, they soon become noisy and loose jointed, if, indeed, with the majority of them they are ever entirely free from these plagues. Reciprocating motions having numerous joints, however well fitted at first, can never be kept long without looseness and noise. Trips and dashpots are noisy at all times, and no one seems to consider it a fault, but noise in any form in machinery is only the evidence of wear and tear, and no machine can be considered perfect that is noisy in working.

To the repairer there is but little to say in this connection. Each case must be dealt with on its merits. Hardened steel pins, holes carefully rimered out, and case hardened if they move on the pins, are the chief repairs. Trips are usually fitted with renewable steel rubbing plates.

Corliss valves are made either parallel or taper; the parallel ones are usually split down and sprung into their seats, or are only segments of a circle and are kept to their seats by the pressure of steam. Taper valves can be adjusted for wear by drawing into their seats in the same way as a plug cock. They all require good lubrication, and when worn are found to be cut and grooved in the direction of motion, when they require to be turned up or renewed, and the seats bored out.

Cranks, Crank Shafts and Connecting Rods.—The efficient working of these depends chiefly on the accuracy of lining up.

Running out of line or out of square with the centre line of the engine will quickly give trouble in the crank pin brasses and even the cross-head centre. The wear of the crank shaft brasses may be responsible for this to some extent, especially if the fly-wheel bearing is worn low, or if the gearing or main drive tends to pull the shaft out of square. If both crank shaft bearings wear equally one way no trouble will be experienced, but this rarely happens, and of course the vertical wear does not tell much on the working. When it is found necessary to fit new brasses, it is desirable to try the truth of the lining up. It will frequently be found that the wear of brasses has been taken up by loose pieces of sheet iron and other kinds of temporary packing. The fault of all these expedients is that they do not fit or give an even bearing to the brasses, which get loose and wear out of shape.

Incipient flaws in a crank shaft forging often begin to show after working some time, even many years in some cases, and as they inevitably extend, it is seldom safe to continue to use the shaft unless it has clearly a considerable margin of strength, or the flaw is in a part of the shaft not subject to the torsional strain of the fly-wheel. In a few cases it will be possible to shrink on wrought-iron or steel hoops to reinforce the weakened shaft; but before doing so it is desirable to test the extent of the flaw by jamming the gear or crank by a strut, and springing the shaft round against it in such a way as to tend to open the crack. This can usually be done by leverage on the fly-wheel. Oil rubbed into the crack will find its way to the end of it, and show by working out how far it extends.

For temporarily repairing broken shafts, see pp. 128–130.

Another frequent source of trouble is the key and key way; generally that of the fly-wheel. This arises from bad fitting at first, or else the key is too small or too shallow to hold sufficient surface at its sides, as Fig. 94; the metal then crushes and the key loosens in consequence. A key that is too deep, on the other hand, will become loose by rolling on its centre (see Fig. 95) and gradually approximating a circular figure. In the first case the remedy is to cut the key seats

deeper, and in the second case to cut them wider. Keys should invariably be made of steel: tool steel (untempered) for ordinary sizes. Large keys will be found to do best if made of mild steel. It is, perhaps, hardly necessary to say that all keys should fit all over the top and bottom sides, but

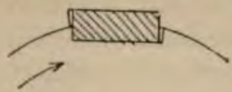


FIG. 94.

FIG. 95.

should never be too tight in width. A key that is tight in its width, or has any taper in width, will in all probability burst the wheel boss. In cases where a wheel has given much trouble from the key working loose, it is best to fit a second

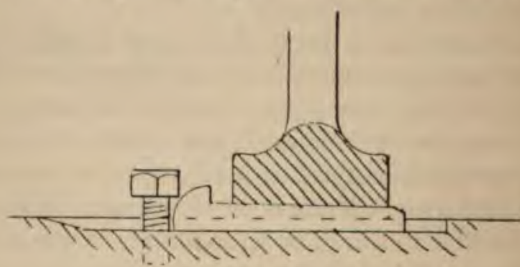


FIG. 96.

key at right angles .to the other; this will usually effect a radical cure. A set screw tapped into the shaft behind the key head is often desirable as a safe-guard, where disastrous results might follow the loosening of a fly or other wheel (Fig.

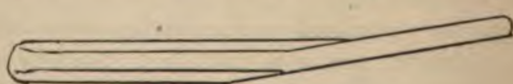


FIG. 97.

96). Key drifts or drivers are shaped as Fig. 97. Very tight keys can often be loosened by warming the part and putting on some paraffin or turpentine, which soon eats its way round the key seat; but if this does not effect the loosening it is necessary to heat the wheel boss by a portable or temporary fire,

and then chill the shaft by pouring water on it at both sides of the wheel: it can then generally be driven out.

New crank shaft brasses ought to be finished boring *in situ*, otherwise they may not line with the shaft journals. Brasses should be cast of a good mixture of *new* metals, not scrap, and hard in proportion to the weight of the strap and fly-wheel. Common metal soon scores and grooves the journals. The shaft journals also should—if grooved or much worn—be turned up true, and the brasses scraped to a good fit after boring; this will usually prevent heating. Oil grooves should be cut in deeply, and the rounded corners carefully fitted. An outer crank shaft bearing is very desirable whenever possible, as an overhung fly-wheel causes very unequal wear.

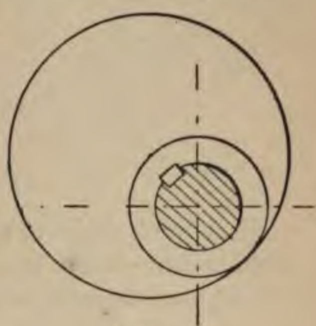


FIG. 98.

Disc cranks are now commonly used in place of the older crank arm, and being of cast iron are safer, and are easily balanced by thickening the part opposite the crank pin; but this is sometimes provided for in the rim of the fly-wheel. But the amount of balance necessary is seldom calculated, and, as a consequence, seldom as effective as it should be in steadying the running of the engine; it thus becomes necessary to adjust the balance when steady running is imperative. There are various methods of doing this, by fastening on additional weight opposite to the cranks. The greater the radial distance of the centre of gravity of such weight from the shaft, of course the smaller will be the required weight; but for various reasons the radial distance should approximate to that of the crank pin as near as may be. Where it is not convenient to apply the weight to the crank or crank disc, an idle eccentric answers the purpose (Fig. 98), and can be fixed anywhere along the shaft, or even bolted to the main eccentric at the proper angular position.

It is very important that the crank or crank disc should

be a good fit to the shaft and well keyed up, in order to bear the irregular and intermittent strains to which it is subjected in working.

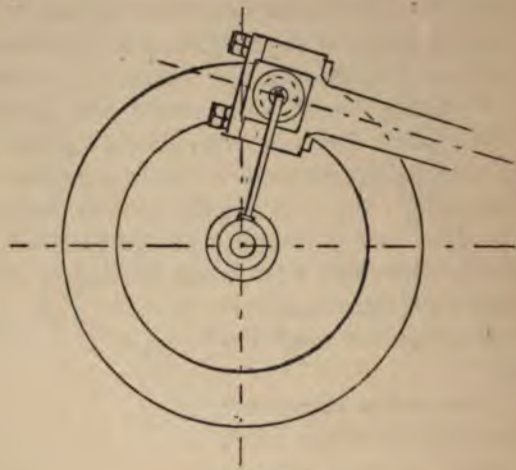


FIG. 99.

Bent crank shafts or connecting rods, that is, those accidentally bent—which may happen from any sudden stoppage or heavy resistance from fracture of teeth in gearing, broken

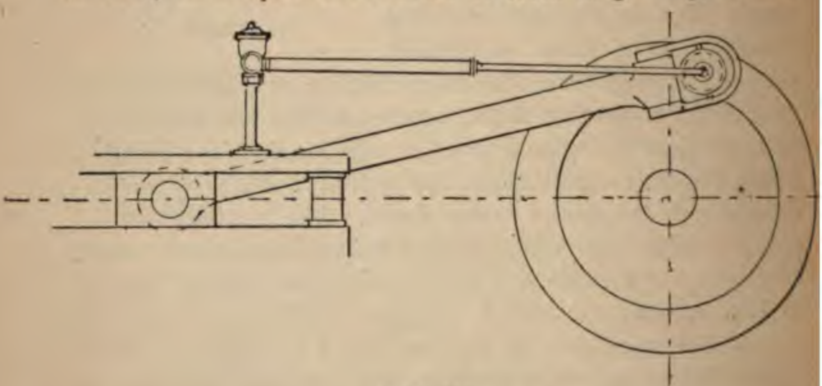


FIG. 100.

machinery, jammed gear or accidental obstruction of any kind, or even water in the cylinder—must of course be straightened; this can only be done while hot (at a black heat is best), and

should then be tested for accuracy between the centres lathe, after which they can be polished again.

Connecting rod ends are of many patterns, though varieties e marine type are now generally replacing the strap end; the great essential—after uracy and fit—is thorough ication, especially at the k pin. A thoroughly effi- t lubricator, however costly, well repay its cost; the nary cups are unsatisfactory use they throw the oil out, cannot readily be supplied n running. The central cup tube, as Fig. 99, is one of best plans in use; another is the telescope tube oiler, 100, and Fig. 101 shows rank pin oiler for vertical nes; but if a cup is used hould be a closed one, and e enough to contain a day's ly; those with syphon tube wick seem the most effec- All brasses should be made utt joint closely, when just e enough to turn freely, and n too loose taken out and joint faces filed or planed n to a good fit again and red or bolted up tight. plan makes a much stiffer better wearing job than

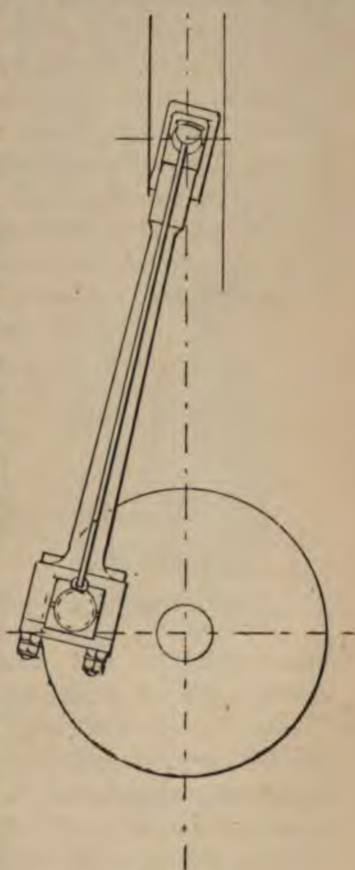
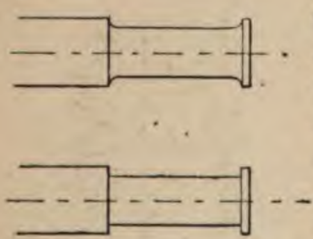


FIG. 101.

e the brasses are loose and at the mercy of the gib and r, and of him who knocks them up. In fact, taking the age engine-driver, or indeed engine-builder, it is not safe to to his ideas of discretion in either knocking up cotters or ving up pedestal brasses. There cannot be the slightest

doubt that an engine works better when every part is rigid, without play or looseness of any kind. When brasses are left slack with an open joint, the entire bearing is of loose parts with a tendency to increase their looseness, whereas, when close jointed and screwed up tight, the bearing is rigid and steadier in every way, and it will be found that the brasses last much longer. Connecting rod brasses are frequently too short to wear well, and as they can seldom be lengthened the only remedy is to make them of hard metal, such as phosphor bronze. The ordinary rule that the length of brasses should be from two to two-and-a-half times the diameter of the shaft is seldom adhered to with connecting rods. Rounded angles, (Fig. 102) are also preferable to square ones (Fig. 103), as the former do not weaken the shaft or crank pin so much as square ones, because in the latter the abrupt change from a smaller diameter to a large one is a source of weakness, and a starting point for flaws and cracks when any undue strain is put on.



FIGS. 102, 103.

Lubricators.—Regular and efficient lubrication of all wearing parts is absolutely necessary to ensure smooth working, a minimum of friction and wear and tear generally, and as a consequence of these, economy in power and durability. The quality of the oil used is as important as the design of the lubricator. The ideal of perfection in lubrication is perhaps most nearly approached in the marine engine, in the method almost universally adopted of supplying every working part by tubes from a main oil reservoir, usually by taps to each tube, but this would be better if the automatic system adopted as an essential feature of all gas engines were applied in addition (see p. 145). When we consider that marine engines frequently run for weeks, day and night, without stoppage, a feat that few land engines are capable of, the value of, and indeed necessity for, a perfect system of lubrication becomes apparent, and if good for the marine engine, why not for the

engine? which now depends generally on the "man he oil can," and his varying moods and methods, who ently puts half a pint of oil into the cylinder before ng, "to last all day," neglects the crank pin because it ound too fast for him, and makes up for this by over- g the fixed bearings. This rule of thumb system surely to be superseded by some simple and effective auto- oil feed. The sight feed lubricator (Fig. 104) is only a owards this, enabling the engineer to dispense with the n as far as the cylinder is concerned, but does nothing le other parts of the engine. Besides this, sight feed ther cylinder lubricators are m fixed so as to be really ive; some deliver the oil the steam pipe, to be carried th the inflowing steam in some but, as you cannot grease 1, and its inflow is seldom at a speed as to blow the oil into ay, this plan is generally delu- others fix the lubricator on ylinder, where no doubt some e oil, especially in the vertical le, does its work, while the s blown out into the exhaust; s fix it on the steam chest, from 1, if it has (as it should have) a pipe, most of the oil finds ay out with the condensed water. Whether the cylinder piston need lubricating at all is even a moot point, as in there are engines of the marine type running without the cylinders, and with satisfactory results as regards ; but possibly better results would be shown on the friction am if oil were used.

FIG. 104.

he slide valve, valve rod, piston rings and piston rod le parts requiring oil, and should be fed regularly at a proportional to that of the engine. This seems at once dicate automatic oil feed, but at the same time it is

practically impossible to oil all these from one ordinary lubricator fixed on the cylinder or steam chest, and we venture to recommend in preference the design shown in

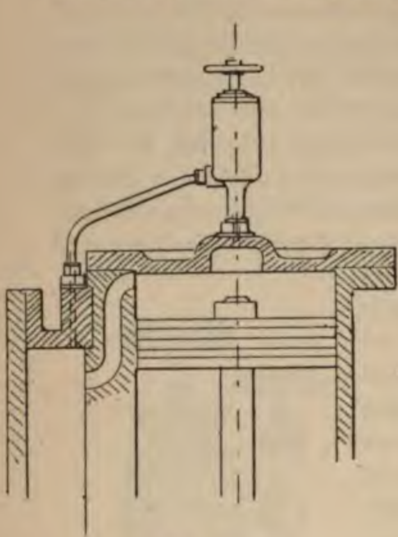


FIG. 105.

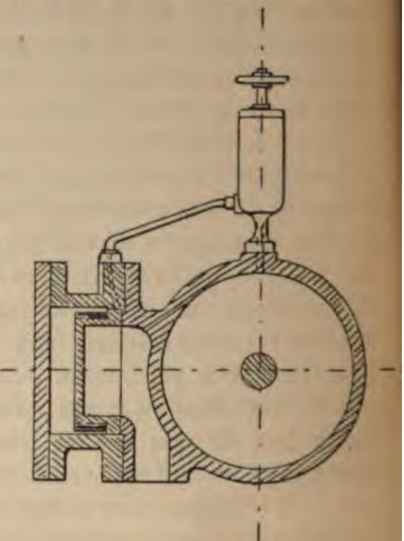


FIG. 106.

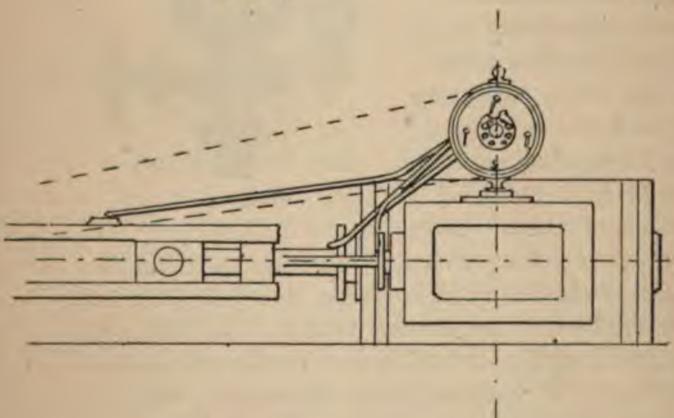


FIG. 107.

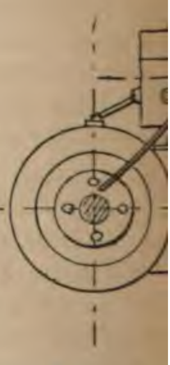


FIG. 108.

Figs. 105 and 106 for vertical and horizontal engines, in place of the usual half useless oil cups, and we also submit a design of automatic oil feed that can be applied to any

engine with great advantage. It consists of an oil drum, Figs. 107 and 108, containing a small spindle revolved slowly by the engine; the spindle carries as many revolving wheels with suspended wires as there are separate feeds required; the wires dip into the oil on the lower side, and each carries a drop and wipes it off into a small cup, from which it is led by a tube to the point required. Those that supply the cylinder and slide valve, and are therefore subject to steam pressure, are supplied by passing the oil in from a revolving plug cock, shown in detail, Fig. 109. The cock may have two or more sets of perforations for this purpose, and the number of wire oil lifters may be proportioned to the quantity of oil required for different parts. This apparatus can easily be arranged for any type of engine and for oiling any number of moving parts. Fig. 110 shows the best

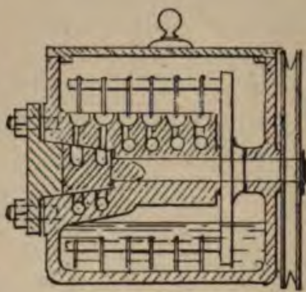


FIG. 109.

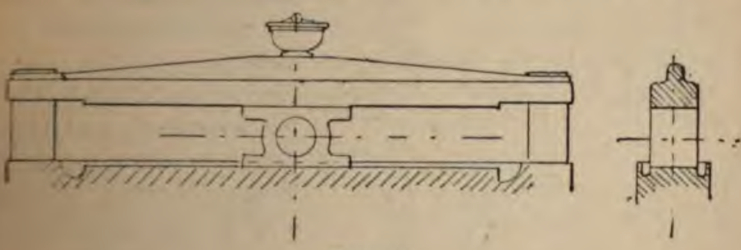


FIG. 110.

known method of slide bar lubrication. Very little oil is needed on the upper side if the engine is run the orthodox way, as Fig. 82, as the pressure during both strokes is on the bottom slide bar. Figs. 111 and 112 show gland oilers.

Gland Packings and Drip Catchers.—It may be assumed that every gland will leak and cause a hot drip that ought to be drained off without getting into the running gear; this is very difficult to accomplish with vertical overhead cylinder

engines. The most effective plan is a pan at the lower end of each piston and valve rod, of section as Fig. 113, if the speed of piston is high, and drained by a jointed or telescopic

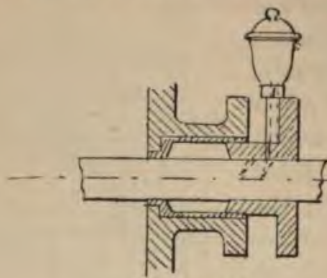


FIG. 111.

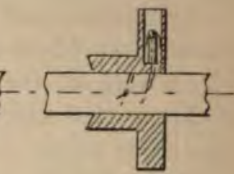


FIG. 112.

pipe. In the horizontal engine the drip can easily be caught by a pan below the rod and drained away.

The lower part of a stuffing box should be tapered, as Fig. 114, in order to compress the lower layers tightly on the rod, as it will be found in practice that the upper layers get the greatest pressure because they expand laterally, and thus bind in the box instead of conveying all the pressure applied down to the lower layers; and this defect is very marked in deep stuffing boxes. The depth of packing should be equal to $1\frac{1}{2}$ times the diameter of the rod, and its thickness one-third the rod's diameter, except in very small rods, where it may be increased to one-half.

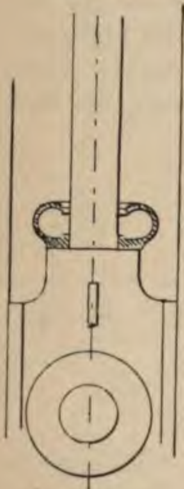


FIG. 113.

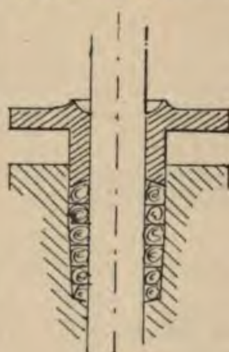


FIG. 114.

Draining Cylinders, &c.—The cocks for this purpose are placed at the lowest points, and are often too small, absurdly so, in many cases; a nominal half-inch drain cock commonly has a hole in the plug not more than $\frac{1}{4}$ inch diameter, so

that scale, red lead, fibres of packing, oil, &c., easily choke them up.

When a boiler primes a good deal, and when warming up before starting, a large quantity of water often finds its way into the cylinders and valve chests and becomes a source of danger. In large cylinders a spring relief valve is generally provided in each cover, and to be effective should be of large area, say one-tenth the diameter of the cylinder. Every engine requires a drain cock also in the valve box, as a considerable quantity of water usually collects there from the incoming steam, especially at starting. In vertical cylinders the upper drain cock is commonly useless, the water being discharged into the exhaust, which from its form favours its exit; but exhaust pipes should, for this reason, and to discharge their own condensation, be so arranged as to lead all the water away from the engine. The steam pipe also should have a fall towards the boiler, and care be taken that the water in it is not trapped by a rise in the pipe, or by the stop valve, as this is a common cause of "water hammer" in the pipes, sometimes causing dangerous fractures. If no other method exists, a small pipe should be fixed to the lowest part of the steam pipe, and led to a steam trap. Various types of steam separators are now made to effect this purpose. Exhaust pipes which ascend, can be drained by a small syphon pipe, as Fig. 115, the height of the syphon depending on the back pressure, as shown by diagram.

Drain pipes are generally all led into one main pipe, which is connected to a drain or convenient rain-water pipe, and it is desirable to connect them by screwed unions, and provide plugs or caps by which they can be readily cleaned.

Drain pipes rarely have sufficient attention bestowed upon them, either in designing or cleaning them. In nine cases out of ten they are too small in diameter. It seems to be commonly supposed that the pressure of the discharging steam and water will scour the pipes; but, as a matter of fact, they often choke with grease, scraps and threads of packing, and sediment, and if the discharging end is not visible the fact of their being choked does not appear. All straight lengths

should end with a cleaning plug; this can be done by using a T-piece instead of a bend or elbow. A small rod can then be used to clean the pipes.

Steam jackets, receivers and steam chests require regular draining, as the condensation in them is tolerably constant during the running of the engine, and correspondingly heavy at starting.

Lagging and protecting Cylinders, &c.—If this is well done and really effective, a large saving of steam results. Asbestos

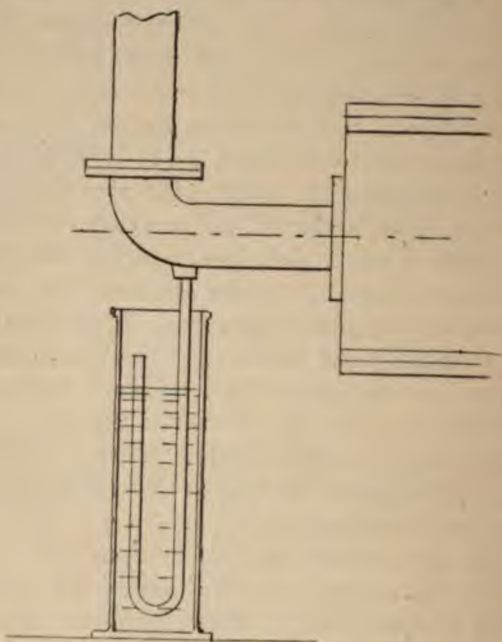


FIG. 115.

wool or slag wool are the best materials, and may be enclosed by wood laggings, or the more modern Russian or planished sheet-iron coating. Wool, felt, sawdust and wood all become charred in time, and do not effectually retain the heat. Asbestos boiler composition will do if laid on at least 2 inches thick, but a less thickness is ineffective. The covers are seldom coated, but need it quite as much as the cylinder

walls; but if dished as Fig. 116, filled with packing and covered by a polished plate, the finish is not impaired, and a useful saving of steam is effected. The same may be said of the steam chest, which is as frequently unprotected, or only coated round its edges; but, inasmuch as the steam is always in the steam chest at the full boiler pressure, it is clearly of advantage to minimise its condensation.

Governing.—All governors are centrifugal, that is, depend on the centrifugal action of revolving weights to regulate the admission of steam. The different methods of applying such weights and of connecting them with the valve gear are too numerous to detail; but there are several well-defined classes of governors: (1) those that have revolving balls acting

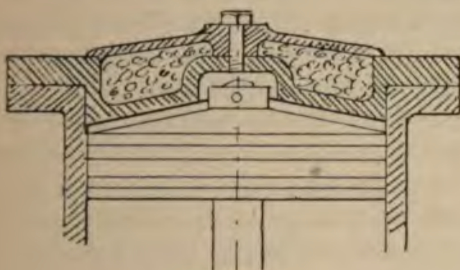


FIG. 116.

directly on the regulator; (2) those that combine balls with springs to modify their action; (3) those in which balls act upon weights, and raise them at the same time that they act on the regulator gear, as Porter's governor. In these, therefore, the weights replace the springs of the second class; (4) crank shaft governors, in which the weights revolve with the crank shaft, and in opening out by centrifugal action against springs, vary the throw of an eccentric operating a cut-off gear; (5) liquid governors, in which a drum filled with liquid contains a revolving fan or paddle, which by friction of the liquid, which it drives round with it, carries the drum round against the increasing pressure of a spring or of a weight wound on a volute, which motion is conveyed to the governor gear. Allen's governor is of this type.

Of these the first three classes are very largely used; but the fourth class, or crank shaft governor, is now becoming the favourite. Some makers will now, in fact, guarantee their engines to run with only 3 per cent. variation when the whole load is thrown on or off, which is certainly a remarkable triumph in this particular branch of steam engine economy.

The defects of governors are: (1) sluggishness; (2) over-excitability. A sluggish governor takes too much time to follow up the variations of speed of the engine, either in slowing down or gaining speed. Such a governor is of no use on saw-mill engines or hoisting engines, where the load is thrown on and off almost instantly. This is generally due to the balls being too heavy or the throttle gear too stiff to move readily. Common butterfly throttle valves are of very little use to govern an engine; they do not act till nearly closed and also open all at once. They should be replaced by equilibrium valves with V-shaped ports.

On the other hand, an over-excitable governor moves, not too rapidly, but overruns the engine variations, perhaps shutting off the steam altogether for a moment or two, and oscillating from full open to shut with every variation of speed. This is bad, because it throws on and off the steam pressure, and renders the engine unsteady and jerky in its efforts at the crank pin, throwing all the regulation on the fly-wheel.

In this case it will generally be found that the governor balls are too small and light, or if heavy enough, are driven at too high a speed; it is desirable, then, to try other sizes of driving pulleys temporarily, until the best speed is found by experiment.

With the fourth class of governor, viz. crank shaft cut-off governors, this trouble does not occur. The cut-off can be varied to suit the play of the governor, and this can to some extent be adjusted by its springs.

CHAPTER V.

SPECIAL TYPES OF STEAM ENGINES.

WE have in Chapter IV. dealt with steam engines in general, the features of which are common to all, but there are many variations from the common types of horizontal and vertical engines that involve special treatment and are liable to particular faults and failures.

1. *Portable Engines.*—These are essentially combined engines and boilers on wheels, and practically, experience has developed them into one form, the horizontal tubular loco-boiler with a horizontal engine fixed on top of it. The boiler does not differ materially from the ordinary locomotive form, the repair of which has been dealt with in Chapter II., but the cylinder, crank-shaft bearings, cross-head guides, feed pump, &c., are all, as a rule, bolted to the boiler, which thus serves also as base plate to the engine. This plan is both theoretically and practically defective, because the boiler is not rigid enough to be used as an effective base plate, and because its expansion and contraction throw the engine out of line and alter its normal lengths. Besides which there are the practical difficulties of fixing the parts independently to a cylindrical base, which latter cannot be turned or planed to any true base line, and from the trouble that frequently arises from leakage at one or more of the bolt holes through the boiler plate, as rivets cannot be used. Undoubtedly the engine ought to have an independent base, bolted to L-irons or plates riveted to the boiler in such a way as to allow for expansion and contraction. As it is, however, it becomes a serious matter to carry out any important repairs to the cylinder, &c., because they must be detached from the boiler, and joint remade and the cylinder lined up afresh. The starting valve and levers are generally fixed inside the boiler, for what reason it is impossible to say, as these fittings do not need any special amount of heat, nor are they unsightly; in fact, they would

be infinitely better attended to outside, where the pins and joints could be lubricated. As it is, they frequently run till so corroded and worn that something breaks before any attention is given to them. The boiler man-holes should be placed so that all the interior can be got at, and the tubes arranged in rows so that a scraper can be used between them. This is very seldom the case, and, as such engines frequently use very bad water, the boiler is liable to get very foul.

The working parts of the engine often suffer much from the grit and dust discharged from the chimney, and for this reason should be covered in some temporary way whenever possible.

In the details of construction of the engine a considerable amount of perfection has been attained, due, no doubt, to much competition and the desire to excel, but some of the smaller economies referred to under the headings of lubrication and coating boiler and cylinder might be given more attention with advantage. Coating is only partially practised, and the lubrication is of the "man with the oil-can" type. Competition in price accounts, of course, for some of this. Compound portables are now being introduced, and more economical cut off and automatic expansion gears.

2. *Traction Engines, Road Rollers and Ploughing Engines* are of the portable type of engine, but self-propelled, and as they run over very rough surfaces are liable to heavy strains and jolts, that necessitate a very strong construction; the most ordinary injuries result from rough treatment and accidental sinking into holes, &c., which strain the frame, bend the axles and shafts, and break even the swivelling gear. The pitch chains require renewing when worn, or taking up a link to tighten up, as the wear of centres lengthens them. Brakes suffer a good deal from wear and strain and should be kept sound and reliable at any cost, or serious accidents may result. The engine and boiler proper need no special mention except that as they are fitted with reversing gear it frequently needs attention. The feed pumps and valves suffer from grit and bad water and frequently give trouble and cause total stoppage (see pp. 94–98).

All engines liable to rough treatment, such as these, ought, in our opinion, to be provided with two feed pumps, or a pump and an injector; but the latter are not so reliable with indifferent water and unskilled attention. The pumps could be made in one casting so that one eccentric and rod could be connected to either of them, and so allow the one out of order to be repaired without stoppage. In some cases an independent steam donkey pump (see p. 94) is fixed on the engine and the feed pump only run occasionally. These pump rams often wear badly because they are insufficiently guided, the angular motion of the rod tending to wear the gland and neck oval. If fitting a new pump bore it throughout to fit the ram, or else deepen the gland and neck to nearly the length of the ram, so as to guide it effectually. There should always be a check valve between the pump and boiler; and to enable this valve to be examined when working, there should also be a brass plug valve between it and the boiler. Screw down valves do not answer well in such positions, as the current of water soon cuts the seatings. The boilers should be frequently cleaned and blown off, and placed under the care of a Boiler Insurance Co., who will see that it is kept in order; and the engine driver should be provided with all proper and useful tools to attend to the casual repairs, gland packing, tube cleaning, &c.

3. *Semi-Portable or Undertype Engines.*—These may be described as horizontal engines with a locomotive boiler above them and resting on the same base plate. They have the advantage of compactness, steadiness and solidity, and are much used where space is limited. Our experience with them has been generally satisfactory, but there are some points of design that cause infinite trouble sometimes. One of these is the universal plan of supporting the smoke-box on the cylinders and valve chests by a saddle casting. This, when the valves are between the cylinders, gives rise to great difficulties in getting at the valves and valve gear. Leakage from the tubes and the hot soot and corrosion also go deeply into the steam passages and castings below the smoke-box, and sometimes eat completely through them, so that the boiler

has to be lifted off and new castings made, machined and fitted. This is undoubtedly a serious error of design; the smoke-box should be independently supported, and the cylinders, valve chests and steam connections all arranged to be got at or removed without interfering with the boiler support. The best designs place the valve chests outside the cylinders, where the valves and gear can be readily seen and kept in order. These engines, from their solid construction, usually run very steadily, are fitted with automatic cut off gear, and are fairly economical in working. Compound engines of this class are now manufactured. This type of engine is much superior to the portable in steadiness, stiffness and solidity; the base being heavy, and vibration prevented by the weight of boiler, &c., resting upon it.

Vertical Combined Engines and Boilers.—Formerly these, like the modern Portables, were constructed so that the cylinder, guide bars, &c., were fixed independently of each other to the boiler shell, a bad arrangement that has been happily superseded, the best engines now being detached from the boiler, but fixed to an extension of the same bed plate, which forms the ashpit of the boiler, and in some cases the feed tank. Thus arranged they involve no special repairs other than those previously noted as peculiar to vertical engines and boilers (see Chapters I.–IV.); they have an advantage over the semi-portable or undertype engines, in occupying less floor space and in being more accessible all over. The boilers are usually set in a recessed ring in the bed plate, which is neat but has the demerit of harbouring wet, coal-dust, &c., which soon corrodes the base ring; there should be a small open space left under the lower edge of the boiler to prevent this. Three or four small iron blocks answer the purpose very well. This type of engine is much superior to the portable in steadiness, stiffness and solidity; the base being heavy and vibration prevented by the weight of boiler, &c., acting upon it.

CHAPTER VI.

PUMPING ENGINES AND PUMPS.

PUMPING engines are of numerous forms and sizes, from the steam donkey to the great Cornish or water-works engine. They have one feature in common, which is that they run at comparatively slow speeds and against a constant resistance on the pumping or working stroke, so that, if double acting, there is not much to be gained by high grades of expansion. Engines with single acting ram pumps and a light suction stroke can be worked with higher grades of expansion if fitted with a good fly-wheel proportioned to the average resistance.

The Duplex Pumps, a modern favourite type, take steam throughout the stroke, and have no fly-wheel or crank shaft to equalise the load; the piston speed is therefore approximately even throughout the stroke, without slowing down at each end, as in the fly-wheel types. Consequently the water is started and stopped suddenly, a feature that, theoretically at least, is open to serious objection, and in fact in practice, when pumping against high lifts, is bad in every way. These pumps can lay no claim to economy, for obvious reasons: the clearances at the ends of the steam cylinders are large, and what is worse, variable; the engines frequently run with shortened stroke, and if let out are likely to knock the covers out; the stroke varies frequently with the speed and the pressure of steam; and altogether, excepting the fact of their compactness, we are at a loss to understand the grounds of their popularity.

The principal qualifications urged in their favour by makers are the absence of all revolving parts, fly-wheel, crank shaft and connecting rod, their consequent compactness, and the reduced amount of attention they need in consequence. There is no doubt however, that their great feature is the construction of the pump and valves, using in some cases a

double acting ram working in a sleeve, generally without packing, and employing a large number and area of valves, and large and direct waterways ; others use leathers or piston rings.

Figs. 117, 118 and 119 illustrate three types of these pumps, manufactured by Messrs. Frank Pearn & Co., Manchester, Fig. 117 being a horizontal high pressure pump

FIG. 117.

for ordinary lifts, Fig. 118 a similar pump for high pressure water for accumulators, presses, &c., and Fig. 119 a vertical pump with a condensing attachment, by which the exhaust steam is condensed by the water above the delivery valves.

The Smith and Vaile Duplex pump is shown in section in

FIG. 118.

Fig. 120. Its special feature is the removable liner to the pump barrel and the simple method of fixing it by studs and nuts inside the back cover. In the steam cylinder separate exhaust ports are cast, as in the Worthington pumps, by which device steam is trapped at each end of the stroke, to form a cushion to the piston and prevent its striking the

vers. The valves and seatings are very accessible and the aterways large.

The repairs commonly needed n these engines are new pump eathers; piston rods turned up or enewed; glands and necks bushed r renewed; new steam piston ings; pump valves renewed—these re generally of the rubber disc ype, and the quality of rubber hould be good, but not too soft, as hey suck deeply into the valve ratings. The valve motion levers, ith slots, blocks and centres, usu- ly work well and give no great ouble. A large and effective air ssel is necessary to take up the dden starting and stopping pe- liar to this type of engine, espe- ally on high lifts.

FIG. 119.

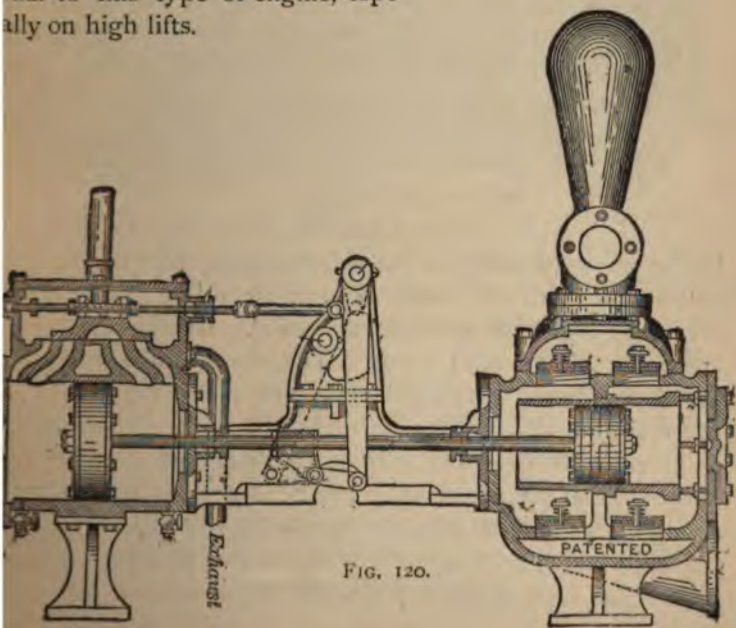


FIG. 120.

Donkey Steam Pumps are very numerous and may be divided into two classes. (1) Fly-wheel pumps. (2) Direct acting pumps with steam moved valves. Those of the first type are by far the most reliable; they are generally single acting and constructed to fix vertically to a wall. The methods of driving the fly-wheel comprise the common connecting rod and crank, the yoke rod and crank, and the slotted cross-head and crank. Nearly all the repairing these pumps so frequently need may be set down to running them at too high a speed, defective or insufficient cushioning by the air vessel, and bad workmanship. Users will not pay a good price for a donkey pump and thus secure a durable article; they buy the smallest size that will do the work and run it at its maximum speed. This is poor economy; nothing is lost by having a pump twice the size, no more steam is used, probably less, as the pump does not slip its water so much, it works quietly, and instead of being always hard at it to overtake the water gauge, can be run at intervals or kept going slowly, and with this treatment will last three or four times as long as the cheap smaller pumps, and save more than the difference of cost in repairs.

FIG. 121.

Very common faults will be found to be the small diameter of the delivery pipe, short bends, small valves and small air vessel. The common brass pump valves are noisy and require frequent renewal. Rubber disc valves are preferable for cold water. The short stroke and quick speed commonly employed soon loosen all the joints and centres, and this is intensified by the hot drip from the cylinder and slide valve glands, so that they become very noisy. They are often badly balanced also, or not balanced at all. This may be partially or wholly remedied by setting the slide valve with a good lead on the bottom port, and little or no lead on the top port, so as to cushion the down stroke.

Fig. 121 illustrates a favourite type of fly-wheel pump by Messrs. Frank Pearn & Co., Manchester, in which the frame or bed plate, air vessel, cylinders and crank shaft bearings are in one casting, and a yoke connecting rod is used with a double steel crank shaft; this arrangement being one of the best, and, in fact, adopted more or less by several makers. The connecting rods should be of cast steel or malleable cast iron, as ordinary cast iron is easily broken by accidental blows.

A duplex pump for boiler feeding, by the Smith & Vaile Co., is shown in Fig. 122, and is fixed horizontally. It is simple in its details and may be used for either hot or cold

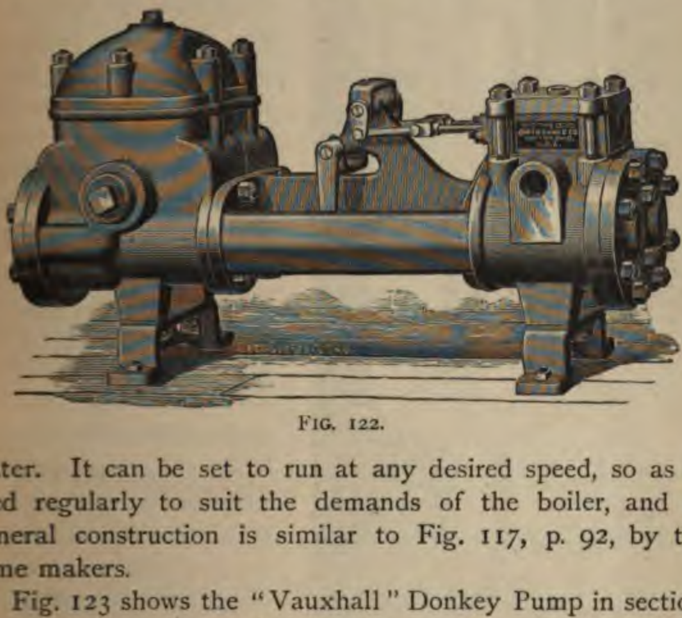


FIG. 122.

water. It can be set to run at any desired speed, so as to feed regularly to suit the demands of the boiler, and in general construction is similar to Fig. 117, p. 92, by the same makers.

Fig. 123 shows the "Vauxhall" Donkey Pump in section, one of the best known boiler feeders and a good example of its class. It is manufactured by Messrs. Alex. Wilson & Co., Limited, of Wandsworth Road, London. It is arranged to fix to a wall or column. The ram and steam piston are in one piece, and the cylinders and frame also a single casting, the valves, bearings and working parts are very accessible. It differs from others chiefly in having a cross-head and

connecting rod to drive the fly-wheel instead of the usual yoke or slotted cross-head.

The second type of donkey steam pumps, with steam moved valves, are frequently very unreliable and troublesome, chiefly because of the very small ports, small piston, auxiliary valves and tappets. The general principle on which nearly all of these work, is that the main slide valve or its equivalent is moved primarily by the pressure of steam on small pistons attached to it, the steam being let in and exhausted from these pistons by a small auxiliary slide valve, piston valve, or three-way cock, operated by the main steam piston striking tappets or levers, or opening small ports at each end of the stroke. There is thus no fly-wheel or crank, no expansion of the steam and no cushioning, in which respect they are on a par with the modern "Duplex," and if given too much steam will overrun

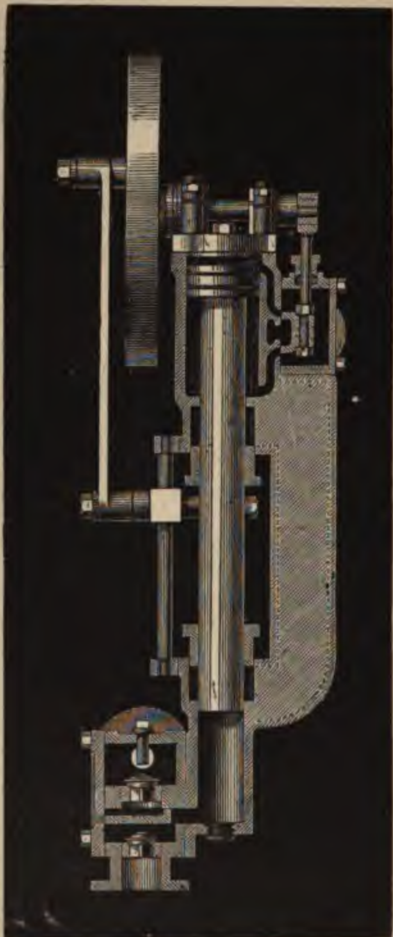
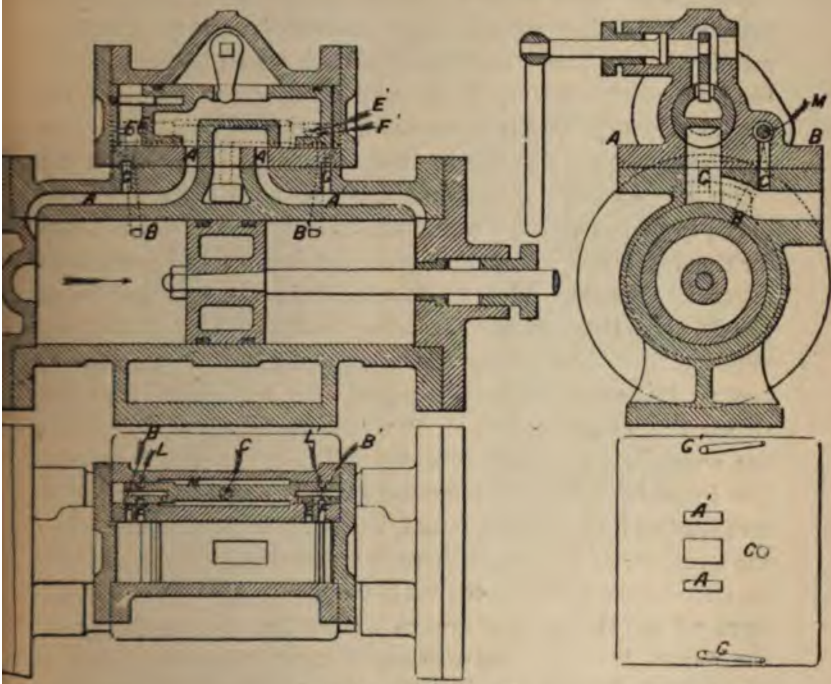


FIG. 123.

their stroke and strike the covers. The pumps are generally double acting and the engines worked horizontally. Slight leakages of the auxiliary valve or pistons will cause them to stop, as also very small obstructions in the little steam

ports. The tappets wear quickly and allow the steam to pass and choke the ports.

A donkey pump whose duty is to supply a boiler upon which the running of an entire factory depends, should be a very reliable engine and as simple as possible. The best pumps of this class are therefore those in which tappets are not used.



FIGS. 124, 125, 126, 127.

Figs. 124, 125, 126, 127 show sections of the Coalbrookdale Co.'s direct acting steam pumps (Parker and Weston's patent).

In these pumps the valves which regulate the admission to and release of the steam from the cylinders are entirely steam moved, no tappets or other mechanical contrivances being necessary. A small piston pilot valve is reversed near the end of each stroke by the steam pressure behind the

piston, which is admitted by the small ports B B to either end of the pilot valve, and exhausted by the hole C. The pilot valve governs the small steam and exhaust passages E E, F F, by which the main valve is reversed. A handle is provided with an arm inside the valve box, by which the valve can be set in starting or moved in case of any stoppage. The same general construction is used in pumps of all sizes and capacities by these makers for ordinary services and for high pressures, mining pumps, &c. There is no fly-wheel or rotative part, and the cushioning of the piston is obtained by the lead of the valve. Some well designed varieties of the double ram type of pump are made on this system.

Directions for Setting-up and Running Pumps.—Do not use pipes of smaller size than the ports of the engine. When long pipes are used it is necessary to increase the size to allow for the increased friction. Especially must this be observed in suction pipes. Use as few elbows, T's and valves as possible, as they greatly increase friction. Use full round bends rather than elbows. Care should be taken to guard against leaks in the suction pipes, as a very small leak destroys the effectiveness of the suction of a pump. When hot water is to be pumped, the difficulty of lifting by suction increases with the temperature. It should therefore be arranged to flow into the pump, if so hot as to vaporise when the pressure of the atmosphere is removed. A large vacuum or suction chamber, placed on the opposite side of the pump from where the suction enters, or on the suction pipe near the pump, is always advantageous, and when the pump is run at a high speed it is a necessity. Ordinary speed to run steam pumps is from 50 to 100 feet piston travel per minute. For continuous boiler feeding one-third to one-half that speed is recommended.

Larger steam pumps for general purposes, such as pumping liquors, filling tanks, vats, &c., draining, pumping sewage, &c., at ordinary pressures, are commonly made of the vertical type (Figs. 128, 129), with overhead cylinders and fly-wheels. In these engines the steam part, that is, the steam cylinder, slide valve and gear, connecting rod, crank and fly-wheel, is

practically the same as in all other steam engines, and liable to similar faults. Some part of the framing is often employed as an air-vessel. Single and double acting rams are common; but the trunk piston is often employed, as it is double acting on the delivering side, with only two valves.

Two single acting rams are also much used (as Fig. 118) instead of pistons, as being more easily packed and repaired. Figs. 128 and 129 illustrate the double acting ram types, as made by Messrs. Joseph Evans & Sons, Wolverhampton. In these the packing is all external and easily

Fig. 128.

Fig. 129.

attended to. Rams are always preferable to pistons for pumping; the packing being external is easily kept in order; the cylinders do not require boring throughout, and it is easier in practice to obtain a sound ram than a sound cylinder casting, and also easier to turn the ram than to bore the cylinder. These are practical points which tell much upon the first cost, and simplify attention in working and repairs, points which we cannot afford to overlook. Cylinder bores are also much sooner cut and corroded by water than the surface of a ram working in a stuffing box; all water cylinders,

in fact, should be brass lined if pistons are employed. The pistons should be fitted with brass rings or leathers ; and rams, though very often made of cast iron, are better and cheaper in the long run if lined with brass. Drawn brass tube can be obtained, sufficiently accurate to be forced into a bored cylinder for lining it without needing a second boring, up to, say 8 inches diameter. Large bores are generally fitted with cast brass liners, turned and bored, driven in by screw pressure, with soft red lead around the joint, and pinned in place unless the covers prevent any end movement of the liner after it has been driven in. But, as cast liners are expensive and often turn out faulty, we prefer to make them of plate metal, bent and brazed at the seam, driven in and bored.

The pump valves employed in this class of pumps are either of the mushroom, wing valve, double beat, rubber disc or flap types, and in a few cases slide or piston valves, having a positive movement by eccentric from the crank shaft, have been employed. The first essential should be sufficient and direct waterway; secondly, accessibility ; and thirdly, durability. An engineer in practice will often be called upon to repair or remedy defects in valves that possess neither essential, or at any rate that are a long way from perfection in these matters. In bucket pumps, of course, the bucket valves are not easy to get at, as the covers must usually be first removed. Then some valve boxes are ingeniously designed so that the delivery valve must be lifted out to get at the suction, or the pump itself taken off to get at the suction valve, or the pipes disconnected to get at any of the valves. These are errors of judgment, and lead to a deal of trouble to save a few shillings in first cost.

Mushroom and Wing Valves, with either flat or conical seatings, become beaten down till they leak badly ; they can be re-bored and turned, and ground in with fine emery or brickdust, or, if too far gone, renewed. They sometimes have too much lift given them, and no screw adjustment to regulate the lift. They should not lift higher than one-fourth of the diameter of the hole. Some valves have not sufficient space around the edge to pass as much water as the valve

itself will do, in which case it is useless to give them more lift; the only remedy is to either bore out the box larger, or turn down the edge of the valve.

Double beat valves require that both seatings shall seat at once, and evenly; and this can be done in the lathe by trying the parts together while facing one up to fit the other, and finishing off with fine emery. These valves require very little lift, usually not more than one-eighth of the diameter.

Rubber Disc valves are very simple and efficient, the larger the better; or, if the dimensions of a single valve would be too great, two, three or more smaller ones are used in the best practice. The thickness should depend on the size of the spaces in the gratings and the pressure, and good rubber should be used. They should not be bolted down tightly in the centre, as this prevents their free movement. The gratings rarely require any ttention. The valves generally ail by embedding themselves n the spaces of the grating nd becoming cut on the beat-ng face.

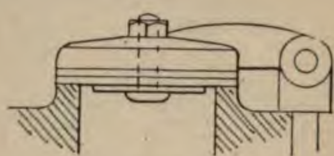


FIG. 130.

Leather or rubber faced flap alves are the oldest type in se. Their faults are that they require a high lift, and there-ore beat hard and wear rapidly; also that the hinges soon vear out, while small obstructions under the hinge end ender them useless. The hinge is commonly too near the alve seating. It should be far enough off to allow the water o pass the valve all round (as Fig. 130). With double flap alves also, it is better to hinge them at the top than at the ottom (as Figs. 131 and 132), because it is much less likely hat an obstruction will lodge under the hinge in the former ase than the latter. The faces are usually of leather, but for hort lifts vulcanised rubber will answer very well; and for igh lifts either vulcanised fibre or metal faces are used; the etal (either brass, phosphor-bronze or hard white metal) ay be sunk in a dove-tail groove either in the valve or seat, r may be attached to either by rivets; bolts are liable to

beat loose. Lignum vitæ wood is also used, embedded in a dovetail groove, end grain towards the valve, as the beating face.

It is, perhaps, needless to say that neither leather nor rubber faces may be used for hot water pumps, and that muddy, sandy, or gritty water rapidly destroys any sort of valve faces; this is particularly the trouble in mining pumps and sludge pumps, used in draining and sinking, for which flap valves are almost universally employed.*

Valve Boxes, Waterways, and Air Vessels.—The old practice in these matters has been of a cheese-paring character, by which all the waterways have been cut too fine, somewhat on the lines of steam and air valves and passages; but steam and air are expansive and elastic fluids of comparatively small

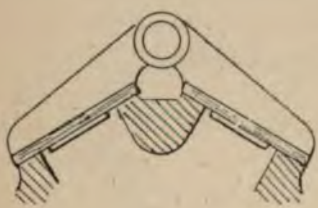


FIG. 131.

FIG. 132.

weight, while water is both heavy and practically incompressible; its inertia, friction and eddies add to the difficulty of moving it in restricted and indirect passages, so that we find in modern practice very large spaces provided around valves in valve boxes, pipes and the pumps themselves, with the object of churning the water as little as possible, and also making its flow as direct and unobstructed as may be. It seems needless to repeat that the valves should be very accessible, the pipes and passages as large and direct as possible, free from sharp bends, angles, or even ledges, shoulders or other internal irregularities, which, although they may not actually reduce the area of the pipe, cause eddies and friction. The ideal pump pipe is one smooth and straight

* For other varieties of these types of valves see 'The Engineers' Sketch Book.'

side, clean and even in sectional area; this, of course, can-
ɔt be got in practice, but the nearer we approach it the
etter, and the engineer who undertakes the repair of these
ill find abundant opportunities for bringing the numerous
adly designed and badly constructed pumps that abound
erywhere, nearer to what we know constitutes perfection.

The rules for areas of ports and valves are very empirical, ecessarily so, as conditions vary so greatly; but it is better ɔ err on the safe side. For instance, a pump forcing water p a delivery pipe to a height of 300 feet—corresponding to a ead of 130 lbs. per square inch—is doing heavier work, nd requires larger passages than one elivering through a short pipe into boiler against the same pressure of team; the inertia of the long column f water, its friction in the pipe, &c., re greater resistances than the elastic ressure of steam. The former will equire a large air vessel, and the atter scarcely needs one if the delivering pipe is short and direct.

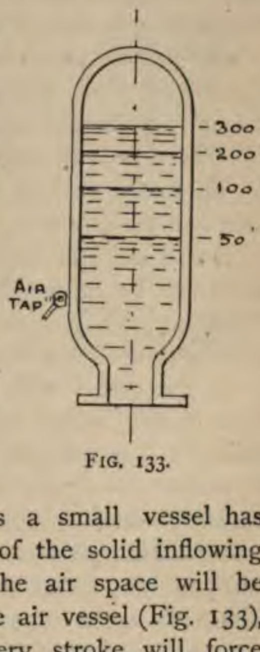


FIG. 133.

Air Vessels are in fact seldom lesigned to any practical rule, probably because in many cases the duty he pump has to perform is not ascertained beforehand, but in such cases arge air-vessels should be provided,—hey can scarcely be too large — as a small vessel has ittle effect in cushioning the impact of the solid inflowing vater. With a head of 300 feet the air space will be educed to one-fifth the capacity of the air vessel (Fig. 133), nd into this space the next delivery stroke will force robably nearly the whole contents of the pump before he 300 feet column starts upwards. Assuming, therefore, that his space should be at least twice the capacity of the pump, t becomes easy to deduce the size of the air vessel when the ressure is known. With a double acting, or still better, a hree-throw pump, a smaller air vessel will suffice than with a

single acting pump, because the delivery of water is more nearly continuous. Air vessels sometimes become ineffective from loss of air, which may be caused by leakage through pin-holes or flaws in the casting, or leaky fittings or plugs in the upper part of the air vessel. Besides these the quality of the water is very variable; in some cases it absorbs the air and carries it with it into the delivery pipe, in other cases it supplies air trapped in the suction in some way, or in the form of gases liberated by the churning of the water in the pump and pipes. An air vessel can be re-charged by an air tap when the engine is standing, but if this does not occur often enough a small air pump must be used to deliver a constant small supply of air into the air vessel.

Air vessels are sometimes fitted to the suction pipes, in which case their action is of course reversed and a partial vacuum produced in them, the effect of which is to produce a more even flow of water and reduce the shock of sudden grip or lift on the suction side. Such vessels need not be more than half the size of those employed on the delivery side.

Small leaks in air vessels are difficult to detect, but can be found by filling them with water and putting on the pressure. They may be drilled out and plugged, or if numerous, or the metal spongy, the most effective remedy is to fill the vessel with thick paint and apply pressure by a hand testing pump till the paint appears outside at the defective spots, when it should be emptied and stood aside for one or two days. It will then be found that the pores of the metal have been fully closed by the paint, which will dry in and close up the casting air-tight. Very minute leaks will cause an air vessel to become inoperative, and such leaks frequently occur round chaplets and studs used to support the core in the mould. For these reasons it is not desirable to use part of the standards or framing of the pump for an air vessel, though this is frequently done.

In some cases a spring piston (Fig. 134) can be usefully substituted for the air vessel, and any leakage past the piston can be easily led away by a small drain pipe. In this apparatus a brass-lined piston, leather packed, works in a bored

linder and is kept down by a spring adjusted to the delivery essure so that it gives and takes with the intermittent action the pump, just as the air in the air vessel does. It has e advantage of certainty in its action, and its action is sible by the motion of its spindle end.

The speed of pumping engines is necessarily slow, and in actice a good deal of the repairing results from too great a eed proportioned to the dimensions and directness of the aterways, which in conjunction with the head should etermine the speed. The speed of the water in the delivery ipe at ordinary pressures should not xceed 300 feet per minute as a standard, nd from this the speed of the pump hould be calculated; thus, for a 10-inch iameter pump, double acting, delivering ito a 3-inch diameter delivery pipe at oo feet per minute, the calculation ecomes—as the area of 10 inch diameter : area of 3 inches diameter : : oo : speed of pump piston in feet per ninute; but with a single acting pump t is evident that, as the column of water s standing during one stroke, only one alf the quantity of water at this speed, vill be discharged that would be devered by a double acting pump; but f an air vessel is used a greater speed han 300 feet per minute may be employed as the air vessel nore or less approximates the delivery to a continuous one. Vith three-throw pumps an air vessel is hardly necessary, nd the delivery is practically continuous.

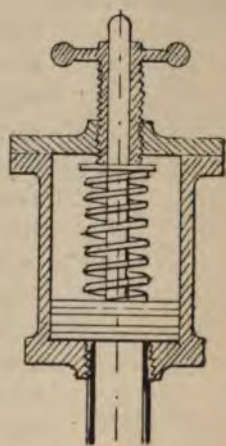


FIG. 134.

High-pressure Pumps for filling Accumulators, Hydraulic Presses, &c.—We find, therefore, that for high pressures the hree-throw pump is always employed in the best practice, enerally single acting, but sometimes of the trunk piston ype or double ram type, in both cases double acting.

High-pressure steam pumping engines for these purposes re commonly direct acting and fitted with two double acting

pumps, because of the difficulty of driving three pumps from two cylinders; but a much more effective engine is one having either three steam and three water cylinders direct acting, or one having two smaller steam cylinders driving by gearing a three-throw crank shaft, and three pumps, as, in the latter, the steam cylinders can be run at high speed and expansively, while in the other two cases the steam pistons run at the same slow speed as the pumps, and there can be no expansion of the steam.

The repairs to such pumping engines are usually confined to the valves, packing, pistons and rods. With the high pressures employed hard packings or leathers must be used.

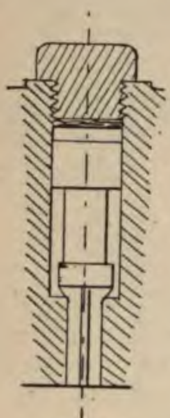


FIG. 135.

Packing is seldom used for pressures above 1000 lbs. to the square inch and requires deep stuffing boxes. Piston rings are of no use and leathers are invariably employed. These should be of good quality, and are best purchased from those who make a speciality of them, and a sufficient number always kept in stock, as their life is very variable; they must not be cut to go over a rod, as it is impossible to make them tight at the cut joint; the rod must be detached from the piston or cross-head and the leather slipped on to it, taking care it has its hollow side towards the pressure in all cases. (See also Hydraulic Lifts, Chapter XXVIII.).

The valves and ports in these pumps are always very small to avoid considerable leakages, as at these pressures a very minute leak will enormously reduce the efficiency of the pump. In reboring such valve seatings take care to leave the seating narrow, as Fig. 135, with the valve well guided and ground in, and the lift not more than one-quarter the diameter. The valves and seatings should be of hard phosphor-bronze. Many of the failures in these pumps may be traced to the use of foul water, it being common to use the same water over and over and only make up leakages. It is also customary to mix soap with the water for lubrication, especially with hard

water; but though this undoubtedly assists the pumps, pistons and leathers, the free acid in the soap and the combination of lime, alkali and ferric oxide produce a flaky harsh grit that injures the working parts, so that it is found in practice that a system of oil or soap lubrication, using *fresh* water, is most satisfactory. The lubricant must be supplied continuously with the suction. If soap is used it can be dissolved in hot water and a small quantity allowed to drip continuously into the suction tank, or if oil is used a lubricator of the sight feed type can be fixed on the suction pipe. A "Stauffer" or a plunger lubricator may be used in the same way to inject a small quantity of oil occasionally into the

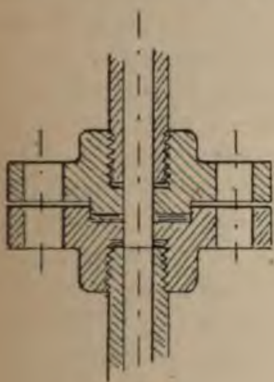


FIG. 136.

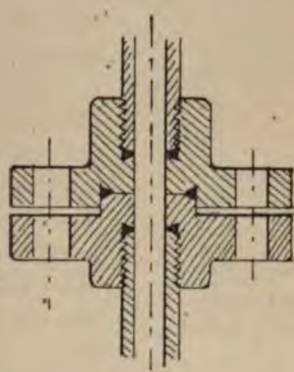


FIG. 137.

suction pipe. Of course if the pump is employed to deliver water for domestic purposes no lubricant can be used, and it is highly desirable that the working parts of the pumps should then be of brass.

High-pressure Jointing.—The joints of pipes, &c., are nearly always flanged for high pressures, and the best materials for joints are leather rings or gutta-percha cord. Soft lead cord or wire may also be used with the best results. These joints are made as shown in Figs. 136 and 137. The flanges should be strongly made with faced spigot and faucet joints, strong steel bolts with faced nuts and heads.

Hydraulic wrought-iron pipes and fittings can be obtained

to stand any pressure, and special heavy screw-down stop valves are made for this class of service, the ordinary steam or water valves being useless, and plug valves very unsafe and impossible to keep tight. Air vessels are rarely required, as in practice the elasticity of the pipes, joints, &c., gives all the cushioning needed with such small deliveries of water.

Air cocks are required on the highest point of every system of delivery pipes, &c., to discharge any air trapped in working; these are made as Fig. 138. If the air is not got rid of a jerky action of the press or accumulator will result.

The speed of the water in the pipes should not exceed 300 feet per minute for pressures up to 1000 lbs. per square inch, and for higher pressures 200 feet per minute may be used, and the speeds of pumps should be calculated from these data.

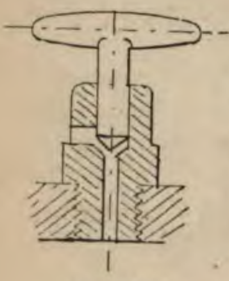


FIG. 138.

Cornish Pumping Engines and large Pumping Engines of other types need but little direct reference here. Their speed is slow, resistance uniform, and they are among our most lasting and serviceable types of machinery. The valve gear of the Cornish engine is peculiar, its speed regulated by a "cataract," and its steam and exhaust valves, of the double beat type, lifted by wipers on rocking shafts. The general construction is similar to the ordinary beam engine, now fast going out of date, but involving no special mention in the way of repairs, the chief of which are in the brasses to rod ends and the shaft and beam centre bearings, which must be kept up in order to maintain the centre lines and clearances, particularly those in the parallel motion. For these it is usual to have a length gauge, by which to correct the lengths of the rod centres when taking up or fitting new brasses, &c.

Engine Room Tools, &c.—It is very desirable and important in all large engine rooms that a full set of all tools for taking apart and readjusting every part of the engine should be provided and kept in good order and handy.

These should include spanners for every size of nut and bolt, or hexagon collars of lubricators, cocks and other fittings, hammers, chisels, files, punches, drills and ratchet braces, stocks and dies, a good vice and bench, a small forge, such carpenters' tools as saw, plane, chisels, gouges, boring bits and brace, screwdrivers; also several special tools and apparatus such as steel, iron and wood wedges, wood blocks and packings, crowbars, lifting eye bolts to raise cylinder covers, pistons, &c., key drifts, caulking tools, gland packing tools, &c.

Lifting tackle is also necessary, strong enough to raise any single piece of the machinery. The best form of this gear is an overhead travelling crane, with either a winch or a set of chain blocks attached: the latter is much the less costly of the two and probably equally efficient. A screw-jack is also useful, and in most cases necessary, also sling chains and ropes.

With a fairly good tool outfit and bench the engineer in charge ought to be able to keep his engine in good running order and to execute a number of small repairs, and by anticipation prevent a good many breakdowns; besides which the tools enumerated are all required when the engine is periodically overhauled. This should be done at least once in from two to five years, according to the extent to which the engine is driven or forced. (See also Chapter XLVII.).

Stores, &c.—In addition to a good set of tools it is essential that a stock of requisites in the form of usable material should be always maintained, and it is bad policy to allow these stores to run short. They usually comprise oil and grease for cylinders and bearings, cotton waste or sponge cloths—if the latter are used they require washing when dirty. Gland packings of the sizes and qualities requisite for the various stuffing boxes about the engine: rubber insertion, various thicknesses, asbestos millboard, various thicknesses (see pp. 66–69) gauge glasses and rings, tarred yarn, spun yarn, emery cloth and powder, spare bolts, nuts, washers and set screws, spare piston rings, joint rings, red and white lead, paint and varnish, if needed, with brushes and pots, belting

and belt fasteners or laces, spare brasses and other wearing parts. These should have been fitted as near as possible, so that no time is lost when it becomes necessary to change them.

A careful engineer will keep these stores in good order, well arranged, and see that they are regularly replaced and always handy. An indifferent hand will leave them all jumbled together in a cupboard or chest, and never be able to find the article wanted.

Deep Well and Mining Pumps, from their positions and the fact that they frequently pump dirty or gritty water and even thick, muddy or sandy water, are a source of constant anxiety and frequently in a chronic state of bad repair. They are almost invariably of the plunger class, and fitted with flap or double beat Cornish valves. No valve yet designed will long stand the cutting action of currents of gritty or sandy water, which groove and scour the valves and seatings in a very short time. With these conditions all that can be done is to provide spare valves and seatings designed to take in and out with as little loss of time as possible. The plungers, pump rods, balance beams, T-bobs, and other heavy gear rarely give much trouble, and their renewal at long intervals is not a difficult matter. As with the engines, so with the pumping gear; it is very necessary that good cross-beams and lifting appliances should be fixed over the pumps, clack boxes, &c., so that they can be readily handled, and for the same reason all such heavy castings should have wrought-iron lifting eyes cast in at their tops and as near their centre lines of gravity as possible, so that they lift without canting over.

Ordinary Deep Well Pumps for Domestic Purposes are similar in general construction to the last, but of smaller size. It has been the fashion for ages to make them with bucket pistons, whereas the plunger type would be infinitely preferable and far less troublesome; the best are of the three-throw form, with crank shaft overhead, and three wrought-iron rods working in fixed guides to drive direct on the pump cross-heads. Single pumps of this class are often used, and less frequently pairs may be met with. The failures with these pumps will be found to be chiefly as follows: wear an

ear of buckets and leathers, wear of glands and packings, ump liners worn out, joints defective, valves and seatings orn out, leaks in suction or delivery pipes, bolts to cylinders r flanges decayed, timber bearers or guide bearers decayed r loose, guides and rods worn out or rotten, overhead crank haft bearings, connecting rod ends and pins worn out, I-frames loose, crank handle loose, &c.

Repairing Cylinders and Valves.—These are usually of rass and can be rebored, but if too thin may be lined with rass tube or new ones cast; the bolts to covers, &c., should e of brass or copper; screws are always troublesome, strip heir threads and do not hold firmly; new leathers should be requently fitted to the pistons, as old worn leathers, besides eaking, cut the barrel badly. The general fitting up of these umps may be described as plumber's engineering, and it is ime they were designed afresh by properly qualified engineers. The other general repairs to rods, guides, &c., involve no ifficulties; it is only necessary to take care that the lengths re not altered, or the pump buckets will strike the covers. The rods, guides and pumps never, of course, get lubricated, rom their position down the well, and this fact must be llowed for in refitting them.

Domestic Pumps generally are dealt with in much the ame way as well pumps, which they generally resemble, xcepting that there are no long pump rods, and the pump tself is usually in sight and fixed to a plank or wall and vorked by a lever. With these also it is a pity the plunger onstruction has not been adopted; they are constantly out f order through wear of buckets, valves, leathers, pins and ackings.

Balancing.—Something can be gained with all domestic and pumps, whether of the crank or lever type of gear, by areful balancing. Two-throw and three-throw pumps need o balancing, but work more evenly if a fly-wheel is used, ecause a man cannot apply his effort evenly round a crank ircle; the fly-wheel rim should weigh about as much as the umber of men required to work the pump. Thus, for two nen a fly-wheel about 2½ cwt. will suffice. Single pumps

worked by wheel and crank should be balanced by a weight on the fly-wheel arm, placed so as to assist the delivery stroke when the delivery is higher than the suction and *vice versâ*. This weight should be made to slide on the arm if possible, so as to be adjustable to the best position, as found by experiment; when this cannot be done temporary weights should be tied on the wheel until the best effect is obtained, and a weight cast to correspond. Lever pumps work easiest if the lever is weighted or counterbalanced so that the weight assists the heaviest of the two strokes, but so that the down stroke of the lever is about one and a half times as heavy as the up stroke: this divides the work more evenly, and it is easier to push down a pump lever than to raise it, in the proportion of three to two.

Many failures are due to frost. Pump barrels and pipes should be constructed to empty themselves in winter if exposed to frost.

Sewage pumps are remarkable chiefly for their extreme simplicity. Such pumps must be able to pass rags, mud and floating refuse without becoming choked. Pistons and buckets are out of place for such work, and flap valves of large area, hung vertically hinge upwards, are the most reliable, as every kind of parallel-moving valve is unreliable. Grating valves with rubber flaps work well if the gratings have large openings to prevent them from choking by filth, and the valve boxes are best constructed with T-bolts with handle nuts, so that they can be opened and closed instantly to remove obstructions. The valve and seat should also be so fixed as to lift out entire in a few seconds, as these pumps are liable to choke frequently—so that accessibility is their greatest feature.

Chain pumps are also much employed for thick and muddy liquids, especially where the water level varies considerably; for which purpose the pump can be made longer or shorter by adding or subtracting links in the chain, and lengthening or shortening the pipes. There are no valves to give trouble. The lower length of pipe should be a fairly good fit to the buckets on the chain, and is best if bored, and

PUMP DIAMETERS AND CAPACITIES IN GALLONS.

Diameter.	Area.	Displacement in Gallons per foot of Travel.	Diameter.	Area.	Displacement in Gallons per foot of Travel.	Diameter.	Area.	Displacement in Gallons per foot of Travel.
	inches.			inches.			inches.	
1/8	·0129	·0005	7 1/4	41·28	1·783	18 1/4	261·5	11·297
1/4	·0490	·0021	7 1/2	44·17	1·908	18 1/2	268·8	11·612
3/8	·1104	·0047	7 3/4	47·17	2·037	18 3/4	276·1	11·927
1/2	·1963	·0084	8	50·26	2·171	19	283·5	12·247
5/8	·3068	·0132	8 1/4	53·45	2·309	19 1/4	291·0	12·571
3/4	·4417	·0190	8 1/2	56·74	2·451	19 1/2	298·6	12·900
7/8	·6018	·0259	8 3/4	60·13	2·597	19 3/4	306·3	13·232
1	·7854	·0339	9	63·61	2·747	20	314·1	13·569
1 1/8	·9940	·0429	9 1/4	67·20	2·903	20 1/2	330·0	14·256
1 1/4	1·227	·0530	9 1/2	70·88	3·062	21	346·3	14·960
1 3/8	1·484	·0641	9 3/4	74·66	3·225	21 1/2	363·0	15·681
1 1/2	1·767	·0763	10	78·54	3·393	22	380·1	16·420
1 5/8	2·073	·0895	10 1/4	82·51	3·564	22 1/2	397·6	17·176
1 3/4	2·405	·1038	10 1/2	86·59	3·740	23	415·4	17·945
1 7/8	2·761	·1192	10 3/4	90·76	3·920	23 1/2	433·7	18·735
2	3·141	·1356	11	95·03	4·105	24	452·3	19·539
2 1/8	3·546	·1531	11 1/4	99·40	4·294	24 1/2	471·4	20·364
2 1/4	3·970	·1717	11 1/2	103·8	4·484	25	490·8	21·202
2 3/8	4·430	·1913	11 3/4	108·4	4·682	25 1/2	510·7	22·062
2 1/2	4·908	·2120	12	113 0	4·881	26	530·9	22·935
2 5/8	5·411	·2337	12 1/4	117·8	5·088	26 1/2	551·5	23·824
2 3/4	5·939	·2565	12 1/2	122·7	5·300	27	572·5	24·732
2 7/8	6·491	·2804	12 3/4	127·6	5·512	27 1/2	593·9	25·656
3	7·068	·3053	13	132·7	5·732	28	615·7	26·598
3 1/8	7·669	·3313	13 1/4	137·8	5·952	28 1/2	637·9	27·567
3 1/4	8·295	·3583	13 1/2	143·1	6·182	29	660·5	28·533
3 3/8	8·946	·3864	13 3/4	148·4	6·410	29 1/2	683·4	29·522
3 1/2	9·621	·4156	14	153·9	6·649	30	706·8	30·533
3 5/8	10·32	·4458	14 1/4	159·4	6·886	31	754·8	32·607
3 3/4	11·04	·4769	14 1/2	165·1	7·132	32	804·2	34·741
3 7/8	11·79	·5193	14 3/4	170·8	7·388	33	855·3	36·949
4	12·56	·5426	15	176·7	7·633	34	907·9	39·221
4 1/4	14·18	·6125	15 1/4	182·6	7·888	35	962·1	41·562
4 1/2	15·90	·6868	15 1/2	188·6	8·147	36	1017·9	43·973
4 3/4	17·72	·7655	15 3/4	194·8	8·415	37	1075·2	46·448
5	19·63	·8480	16	201·0	8·683	38	1134·1	48·993
5 1/4	21·54	·9348	16 1/4	207·3	8·955	39	1194·6	51·607
5 1/2	23·75	1·026	16 1/2	213·8	9·236	40	1256·6	54·259
5 3/4	25·96	1·121	16 3/4	220·3	9·516	41	1320·3	57·037
6	28·27	1·221	17	226·9	9·802	42	1385·4	59 849
6 1/4	30·67	1·325	17 1/4	233·7	10·095	43	1452·2	62·735
6 1/2	33·18	1·433	17 1/2	240·5	10·389	44	1520·5	65·686
6 3/4	35·78	1·545	17 3/4	247·4	10·687	45	1590·4	68·688
7	38·48	1·662	18	254·4	10·990	46	1661·9	71·794

both chain and pipes should be galvanised. Repairs are very nominal: new chains and buckets are usually all that are needed. The chain must, of course, be a good fit to the sprocket wheel.

Centrifugal pumps are constructed similarly to fans, and revolve at high speeds; some of them may be described as in principle circular chain pumps, their action depending chiefly on the accuracy with which the fan blades fit the suction side of the pump case in those that have a tangential suction. Those having central suction, and which therefore draw their water in round the boss, act on the principle of a reversed turbine. In all of them their efficiency depends on their speed, the fit of the blades to the case, and, of course, the design. The main bearings require to be maintained a good fit to the journals, so as to run freely, yet without looseness, and must be quite rigid; they are usually provided with adjustments to regulate the blades to the case. These pumps are not used for high lifts, but are most efficient for short lifts and large quantities of water. They will draw as much as 22 feet on the suction side, and employ pipes of comparatively large diameter.

Pulsating pumps of the "Pulsometer" and "Aqua Thruster" types are useful chiefly for draining foundations and pits and for sinking, because in such positions they can be lowered to their work by a chain and kept at work with little trouble from muddy or gritty water, the only attachments needed being the steam supply pipe and the suction and delivery pipes, for which latter ordinary armoured or wire-bound hose is often used. There is, in general, only one small self-acting working valve employed, which admits the steam to press on the surface of the water, and four large flap delivery valves. There are no pistons or their equivalents, consequently the steam used is largely in excess of that which would work a steam pump of equal capacity, but it is considered that this loss is amply compensated by their handiness, simplicity and small amount of attention required. Improvements are now, however, being introduced by which some degree of expansion of the steam is effected and this loss

duced, as described below, p. 118. The valves are the only arts likely to need occasional repair, and require no special ention; they are readily removed and replaced. These umps will draw from 8 to 20 feet on the suction, and deliver a height depending n the pressure of team used, up to 80 eet, but are seldom ised for very high ifts. As in all other pumps, it is important that the pipes and joints should be perfectly air-tight; mere pin-holes in the suction pipe or pump casting will greatly reduce their efficiency, and even stop them from working. And the same caution as to preventing freezing is necessary here, as these pumps are often left in exposed positions. Cocks are generally provided by which they are emptied when stopped for the night, &c. Fig. 139 is a section of the "Pulsometer," showing the valves and general arrangement.

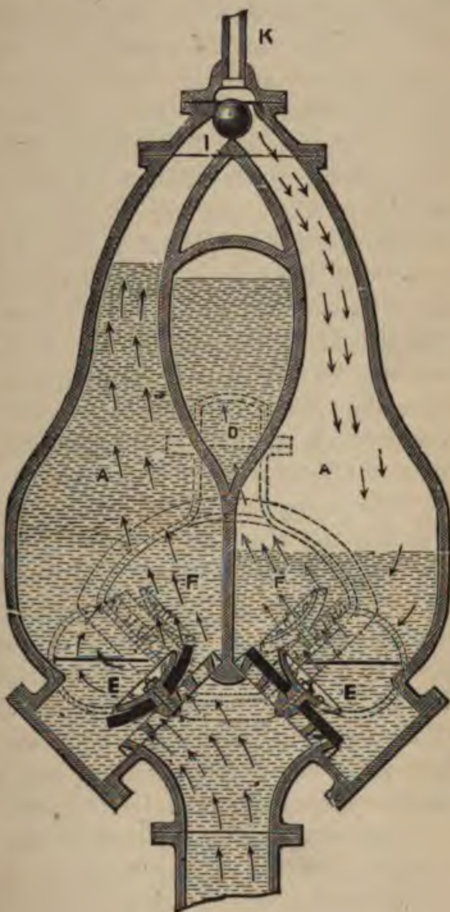


FIG. 139.

Description of the Pulsometer.—The pulsometer consists of a single casting called the body, which is composed of two chambers A A, joined side by side, with tapering necks

bent towards each other, and surmounted by another casting called the neck J, accurately fitted and bolted to it, in which the two passages terminate in a common steam chamber, wherein the ball-valve I is fitted so as to be capable of oscillation between seats formed in the junction. Downwards, the chambers A A are connected with the suction passage, wherein the inlet or suction valves E E are arranged. A discharge chamber, common to both chambers and leading to the discharge pipe, is also provided, and this also contains one or two valves F F, shown in dotted lines, according to the purpose to be fulfilled by the pump. The suction and discharge chambers are closed by covers, accurately fitted to the outlets by planed joints, and readily removed when access to the valves is required; in the larger sizes hand holes are provided in these covers. Guards control the amount of opening of the valves E E. Small air-cocks are screwed into the cylinders and air-chamber, for use as will be hereafter described. These are the general outlines of the construction of the apparatus, and they are sufficient to explain the nature of its operation.

The pump being filled with water, either by pouring water through the plug hole in the chamber or by drawing the charge, is ready for work. Steam being admitted through the steam pipe K (by opening to a small extent the stop-valve), passes down that side of the steam neck which is left open to it by the position of the steam ball, and presses upon the small surface of water in the chamber which is exposed to it, *depressing it without any agitation,* and consequently with but very slight condensation, and driving it through the discharge opening and valve into the rising-main.

The moment that the level of the water is as low as the horizontal orifice which leads to the discharge, the steam blows through with a certain amount of violence, and being brought into intimate contact with the water in the pipes leading to the discharge chamber, *an instantaneous condensation takes place,* and a vacuum is in consequence so rapidly formed in the just emptied chamber that the steam ball is pulled over into the seat opposite to that which it had occupied during

HEAD OF WATER IN FEET AND EQUIVALENT PRESSURE IN POUNDS PER SQUARE INCH.

	Pressure per sq. in.	Feet Head.	Pressure per sq. in.	Feet Head.	Pressure per sq. in.	Feet Head.	Pressure per sq. in.	Feet Head.	Pressure per sq. in.	Feet Head.	Pressure per sq. in.
1	0·43	46	19·92	91	39·42	136	58·91	181	78·40	226	97·90
2	0·86	47	20·35	92	39·85	137	59·34	182	78·84	227	98·33
3	1·30	48	20·79	93	40·28	138	59·77	183	79·27	228	98·76
4	1·73	49	21·22	94	40·72	139	60·21	184	79·70	229	99·20
5	2·16	50	21·65	95	41·15	140	60·64	185	80·14	230	99·63
6	2·59	51	22·09	96	41·58	141	61·07	186	80·57	231	100·09
7	3·03	52	22·52	97	42·01	142	61·51	187	81·00	232	100·41
8	3·46	53	22·95	98	42·45	143	61·94	188	81·43	233	100·93
9	3·89	54	23·39	99	42·88	144	62·37	189	81·87	234	101·36
10	4·33	55	23·82	100	43·31	145	62·81	190	82·30	235	101·79
11	4·76	56	24·26	101	43·75	146	63·24	191	82·73	236	102·23
12	5·20	57	24·69	102	44·18	147	63·67	192	83·17	237	102·66
13	5·63	58	25·12	103	44·61	148	64·10	193	83·60	238	103·09
14	6·06	59	25·55	104	45·05	149	64·54	194	84·03	239	103·53
15	6·49	60	25·99	105	45·48	150	64·97	195	84·47	240	103·96
16	6·93	61	26·42	106	45·91	151	65·49	196	84·90	241	104·39
17	7·36	62	26·85	107	46·34	152	65·84	197	85·33	242	104·83
18	7·79	63	27·29	108	46·78	153	66·27	198	85·76	243	105·26
19	8·22	64	27·72	109	47·21	154	66·70	199	86·20	244	105·69
20	8·66	65	28·15	110	47·64	155	67·14	200	86·63	245	106·13
21	9·09	66	28·58	111	48·08	156	67·57	201	87·07	246	106·56
22	9·53	67	29·02	112	48·51	157	68·00	202	87·50	247	106·99
23	9·96	68	29·45	113	48·94	158	68·43	203	87·93	248	107·43
24	10·39	69	29·88	114	49·38	159	68·87	204	88·36	249	107·86
25	10·82	70	30·32	115	49·81	160	69·31	205	88·80	250	108·29
26	11·26	71	30·75	116	50·24	161	69·74	206	89·23	251	108·73
27	11·69	72	31·18	117	50·68	162	70·17	207	89·66	252	109·16
28	12·12	73	31·62	118	51·11	163	70·61	208	90·10	253	109·59
29	12·55	74	32·05	119	51·54	164	71·04	209	90·53	254	110·03
30	12·99	75	32·48	120	51·98	165	71·47	210	90·96	255	110·46
31	13·42	76	32·92	121	52·41	166	71·91	211	91·39	256	110·89
32	13·86	77	33·35	122	52·84	167	72·34	212	91·83	257	111·32
33	14·29	78	33·78	123	53·28	168	72·77	213	92·26	258	111·76
34	14·72	79	34·21	124	53·71	169	73·20	214	92·69	259	112·19
35	15·16	80	34·65	125	54·15	170	73·64	215	93·13	260	112·62
36	15·59	81	35·08	126	54·58	171	74·07	216	93·56	261	113·06
37	16·02	82	35·52	127	55·01	172	74·50	217	93·99	262	113·49
38	16·45	83	35·95	128	55·44	173	74·94	218	94·43	263	113·92
39	16·89	84	36·39	129	55·88	174	75·37	219	94·86	264	114·36
40	17·32	85	36·82	130	56·31	175	75·80	220	95·30	265	114·79
41	17·75	86	37·25	131	56·74	176	76·23	221	95·73	266	115·22
42	18·19	87	37·68	132	57·18	177	76·67	222	96·16	267	115·66
43	18·62	88	38·12	133	57·61	178	77·10	223	96·60	268	116·09
44	19·05	89	38·55	134	58·04	179	77·53	224	97·03	269	116·52
45	19·49	90	39·98	135	58·48	180	77·97	225	97·46	270	116·96

the emptying of the chamber, closing its upper orifice and preventing the further admission of steam, allowing the vacuum to be completed; water rushes in immediately through the suction pipe, lifting the inlet valve E, and rapidly fills the chamber A again. Matters are now in exactly the same state in the second chamber as they were in the first chamber when our description commenced, and the same results ensue. The change is so rapid that, even without an air vessel on the delivery, but little pause is visible in the flow of water, and the stream is, under favourable circumstances, very nearly continuous. The air cocks are introduced to prevent the too rapid filling of the chambers on low lifts and for other purposes, and a very little practice will enable any unskilled workman or boy to set them by the small nut so that the best effect may be produced. The action of the steam ball is certain, and no matter how long the pump may have been standing, it will start as soon as dry steam is admitted.

An improved self-acting expansion valve has recently been added to the pulsometer called the "Grel," by which a considerable saving of steam is effected. The steam, instead of being let on at full pressure throughout the stroke, is now automatically cut off at about half-stroke, effecting a saving of from 25 to 50 per cent. of the steam ordinarily used. As these pumps will pump such liquids or semi-liquids as mud, liquid cement, slurry and sewage sludge, they have a special field of usefulness. They need no lubrication, scarcely any attention, and have no exhaust steam or frictional parts.

TABLE OF EQUIVALENT HYDRAULIC UNITS.

One imperial gallon	=	277·274 cubic inches
,, ,,	=	·16 cubic feet
,, ,,	=	10·00 lbs.
,, ,,	=	4·537 litres
One cubic inch of water	=	·03607 lb.
,, ,,	=	·003607 imperial gallon
One cubic foot of water	=	6·23 imperial gallons
,, ,,	=	28·375 litres
,, ,,	=	·0283 cubic metre
,, ,,	=	62·35 lbs.

TABLE OF EQUIVALENT HYDRAULIC UNITS—*continued.*

One cubic foot of water	=	·557 cwt.
,, ,,	=	·028 ton
One lb. of water	=	27·72 cubic inches
,, ,,	=	·10 imperial gallon
,, ,,	=	·4537 kilo.
One cwt. of water	=	11·2 imperial gallons
,, ,,	=	1·8 cubic feet
One ton of water	=	35·9 cubic feet
,, ,,	=	224 imperial gallons
,, ,,	=	1000 litres (approximately)
,, ,,	=	1 cubic metre (approx.)
One litre of water	=	·22 imperial gallon
,, ,,	=	61 cubic inches
,, ,,	=	·0353 cubic foot
One cubic metre of water	=	220 imperial gallons
,, ,,	=	1·308 cubic yards
,, ,,	=	61028 cubic inches
,, ,,	=	35·31 cubic feet
,, ,,	=	1000 kilos.
,, ,,	=	1 ton (approximately)
,, ,,	=	1000 litres
One kilo. of water	=	2·204 lbs.
One atmosphere	=	1·054 kilos. per sq. in.
A column of water 1 ft. high	=	Pressure of ·434 lb. per sq. in.
A pressure of 1 lb. per sq. in.	=	Column of water 2·31 ft. high.

CHAPTER VII.

FACTORY AND MILL ENGINES.

THESE are of a great variety of forms. Nearly all the memoranda given under the general heading of steam engines (Chapter IV.) apply to these and may be first consulted. There are, however, some special features that may be usefully particularised. We may divide this class of steam engines into horizontal engines, vertical engines and beam engines. Each of these will be again subdivided into high pressure, high pressure condensing, compound, and triple expansion engines, there are also examples of quadruple

expansion engines in use for driving factories. There are indications that the old plan of driving a large factory by a single large engine will soon in many cases be substituted by that of employing independent engines for each section of the works, because the risks are less and there is an economy obtained in the amount of shafting and belting used, and the friction of same, with—in many cases—an economy in steam, due to the ability to run each section at its best speed, to shut off any section without stopping others; and with modern improvements smaller engines can now be made equal in economy of working to the very large engines ordinarily used, and are much handier to repair and to manage. For paper mills and all works in which some sections of the work are intermittent or irregular, this plan is desirable. For electric lighting and for machines, the absolute and regular working of which is a *sine quâ non*, subdivision is an important matter both as regards engines and boilers, as the arrangement should be such that in case of a breakdown of any one engine or boiler another can be immediately set to do its work. Where the whole work is driven by one large engine this means that a very costly duplicate must be provided; but with the subdivision system a small duplicate engine will suffice. The reason hitherto given for the almost universal employment of a single large engine has been its greater economy in steam and attendance, but this difference does not—or at least need not—exist now. In America the subdivision system is becoming popular, and it is now finding its way in this country.

The type of engine adopted for any particular work must be judged from the following data: space available; economy essential; speed required.

Where space is not of great importance the horizontal engine possesses the greatest advantages. Its weight is well sustained on a simple long foundation giving steady running with great solidity, an important matter with prime movers. All its parts are easily accessible and in sight, without ascending stairs or platforms; it is better balanced than any other type and gives less trouble from drip.

the space available is restricted, either a vertical a wall engine should be employed—the latter may to a massive wall with very little floor space. Of ngines, the overhead cylinder marine type is probably as the running gear is placed low and gives very ation on a good foundation. The working parts are cessible from the floor, but a platform and steps are ecessary to reach the cylinder lubricators, drain cocks ng valve.

nsidering relative economy it should be borne in t the size of an engine has very little to do with its in working beyond a small percentage due to the in internal friction, which decreases as the engine in size. But any important saving must be looked in the steam distribution, by its type of valve gear of expansion. As to the value of the steam jacket are much divided, though, on the whole, the balance ony is in favour of the jacket, that is, when it is coated to effectually retain the heat of the steam nt radiation.

ounding may even be carried too far, and by in-he proportion of internal friction by the use of large ure cylinders and gear, lose more than is gained by ansion. But it is important for economy in a com-gine that a high initial pressure should be adopted; s a strong and well built engine, and for all ordinary two cylinders will give the best results with the r and tear. Three cylinders should only be em-very large engines and under circumstances where t economy of fuel is essential.

eneral types of compound engines exist, the "Woolf" d the Receiver engine, the difference depending upon of the cranks. In the former the cranks are placed ether or opposite one another, and in the latter they ne intermediate angle. In the Woolf engine, there-team is exhausted direct from one cylinder to the in the Receiver engine the steam is exhausted into before it enters the next cylinder, because the piston

in that cylinder is not at the end of its stroke, and therefore not ready to receive the steam at the time that the first cylinder is exhausting. Woolf engines require "barring" gear to turn them to the proper position for starting, for which purpose either a crowbar or long lever engaging with notches or teeth round the fly-wheel rim usually suffices; but in large engines a lever and pawl gear, and in some cases a small barring engine with worm gear and pawl are used for this purpose. It is also necessary for starting these engines to provide a bye-pass to admit high-pressure steam to the low-pressure cylinders.

Compound engines possess the advantage, however, of having the total effort of the engine divided among two or more cranks instead of—as in the single engine—having the whole effort applied to one crank pin, and a more equable rotative energy is thus applied, so that the fly-wheel need not be so heavy as in the single engine, which with a long expansion and dead centres applies a very varying rotative energy to its single crank pin.

Corliss Valve Gear is now much used in spite of its rattle-trap action, because with it a sharp and sudden cut-off is obtained at any point in the stroke without throttling or wire-drawing the steam, as the ports always have a full opening during admission. There are, however, many other forms of trip gear that do the same thing in other ways.

Slide Valve Gear.—With a plain slide or double-ported slide the cut-off can be varied up to about one-half or five-eighths of the stroke, but any cut-off up to say one-tenth or one-twelfth can be obtained by using a cut-off slide in addition; this involves a second eccentric; but with the slide valve the cut-off is always gradual, so that in some cases the steam is more or less throttled or wire-drawn. This gear, however, works quietly and gives little trouble. In large beam engines and Cornish engines the steam is distributed by double beat or Cornish valves, lifted by cams or wipers on a rocking shaft, which is operated by an eccentric; this gear also is capable of any grade of expansion and cut-off, and like the Corliss gear cuts off sharply, but without

the noisy action of the latter. The valves and gear wear well.

Speed.—It is usual to run the engine at about half the speed of the shafting, but the piston speed of the engine should be proportioned to its size: large engines run at about 300 feet per minute, small engines at from 300 to 500 feet per minute, while the specially constructed high speed engines often attain a speed of 900 feet per minute. Excessive speed causes excessive wear and heating, and should always be avoided.

It will be easily seen from the foregoing notes that the cost of maintenance, repair and attention of an engine will depend upon how nearly it approaches these essential conditions, its suitability for its class of work and the treatment it receives.

For treatment of repairs in detail see pp. 51 to 86.

A factory engine should always have power in reserve, that is, should always be large enough to do its work without straining, and with a sufficient margin for any probable or possible additional machinery that may become necessary. The neglect of this causes abnormally frequent repairs and perennial waste of fuel, oil, &c., and shortens the life of the engine seriously.

CHAPTER VIII.

MARINE ENGINES AND CONDENSERS.

MARINE engines work under conditions differing in many essentials from land engines; they are fixed to the wrought-iron structure of the ship's hull, and are subject to many irregular strains in consequence, due to the rolling and pitching of the vessel. All wrought-iron structures are more or less elastic, and the hull of a ship is particularly so, on account of its length, and the torsional or racking strains that are set up by the motion of the vessel. The paddle and

screw shafts are rarely truly in line, every lift of the stern exposes the propeller, partly or wholly, causing the engines to run away unless restrained by a sensitive governor, and the suddenness of this immersion and emersion, or in the case of paddles, the shifting of the resistance from one paddle to the other by rolling, must obviously strain the engines. Compared with land engines of similar type, marine engines are more heavily built throughout; very high pressures are used, 150 to 200 lbs. being common with double or triple compound cylinders and surface condensers, and the utmost economy is attained. A very high efficiency is absolutely necessary, in order to reduce to a minimum the quantity of coal required to be carried on a long voyage. The breakdowns and injuries this class of engines is peculiarly liable to arise from strains caused by the motion of the vessel, propeller blades or paddle floats striking floating or sunken obstructions, bursting of steam pipes, &c., which casualties must be added to the ordinary sources of wear and breakdown that every engine is liable to.

It is impossible to calculate or indeed to foresee with any certainty, the nature of the strains arising from the vessel's motion; they result frequently in breakage of screw shafts, which is at least sufficient evidence of their existence and intensity. The engines themselves are usually massively built and framed, otherwise, being secured to a springy foundation, they would suffer much from racking or straining, and also from vibration or tremor, the tendency of which is to loosen and cause undue wear on every joint and wearing surface. With paddle engines the straining due to pitching and rolling tends to throw the shaft out of line, twisting and loosening the bearings so that it is difficult to keep them and the connecting rod brasses to such a fit as would be considered absolutely necessary on a land engine; the floats striking the water also cause jar and vibration. Almost every marine engine frame works on its bearers and at every joint from these causes; and it is difficult to see how any effectual remedy can be provided; nothing but a solid mass of cast iron or cement as a base would be of any service, the weight of which would be objectionable for other reasons. Various

methods are employed to stay the engines by tie rods and struts secured to beams forming the main framing of the hull, but these add nothing to their stiffness.

In detail these engines do not differ materially from land engines; they are of course fitted with reversing gear, and the guides and cross-heads must be designed to run either way. The old link motion is still largely employed with its numerous joints, but is now being replaced by simpler gear in the latest examples. For notes on the general details see Chapter IV. Special apparatus for continuous lubrication of all the working joints, &c., are provided and are, indeed absolutely necessary (see p. 78).

Auxiliary Engines.—Besides the main engines there are usually various auxiliaries for the minor duties: boiler feeding, bilge pumping, circulating water through the condenser, and a number of deck winches; steam stearing gear; also in some cases electric lighting engines and dynamos, and sometimes an independent air pump and fresh water condensers. Formerly most of these services were performed by pumps attached to the main engines, but it is considered that independent engines are more handy, and can be run without running the main engines. Against this convenience must be set the multiplicity of pipes, valves and connections, and the frequent repairs these small engines entail. The deck winches are exposed to all weathers, and soon become loose-jointed and abominably noisy. The pressure of steam for the service of these auxiliaries should be reduced to below 80 lbs., as, with the conditions obtaining on board ship it is practically impossible to keep the pipes and valves tight with the higher pressures. Copper pipes are always employed except for the largest steam and exhaust pipes, for which riveted pipes of mild steel are becoming substituted. These are fitted with welded wrought-iron flanges riveted on the pipe. Copper pipes, being brazed at the joint, have given way in many cases and caused the most frightful accidents. The straining of the vessel and variable expansion of the pipes has contributed to these accidents, and the extremely narrow and difficult ladder accommodation common in all engine rooms prevents the men from making a hasty exit at

any time. Ships are rarely provided with a sufficient supply of tools for casual repairs when at sea, and as a consequence things are left to be done when in port that would be far safer if attended to at once. Such tools as are at hand are of the roughest description, and frequently there is no bench or even space where one could be fixed, the entire

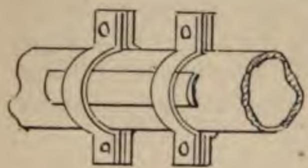


FIG. 140.

FIG. 141.

engine room being crowded with machinery and pipes. This cramming system is much to be deprecated, as it is impossible to satisfactorily keep in order a costly plant where many parts of it are almost inaccessible, and the men have to work under the greatest discomfort and danger. The effec-

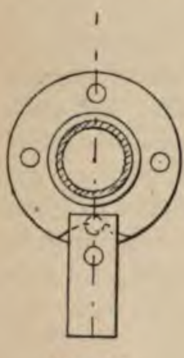


FIG. 142.

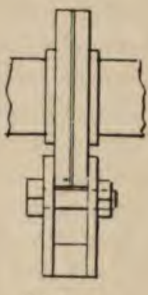


FIG. 143.

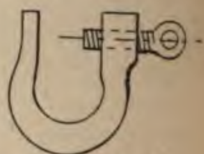


FIG. 144.

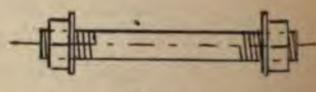


FIG. 145.

tual maintenance of a marine installation depends largely on these matters. It is the experience of every machinery user that where difficulties of access, crowding and other discomforts exist, the machinery will be neglected in the same proportion.

No effective and permanent repairs are ever attempted

hile a ship is at sea, but such accidents as arise are temporarily "fixed up," often under circumstances of the greatest ifficulty. Broken flanges, burst pipes, broken bolts, broken crew or paddle shafts, propeller blades, paddle-wheel floats r arms, are comparatively common failures. The following re among the best methods of temporarily repairing these.

Pipes and Flanges.—Cracks in large pipes are best proected by pairs of clamps A, bolted on, as Fig. 140, and used to hold up a piece of plate, bent to fit the curve of the pipe;

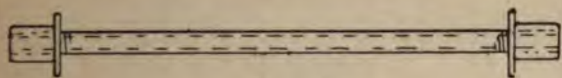


FIG. 146.

under the plate a thick piece of asbestos millboard should be laid. The clamps are easily made from flat bar iron. For small cracks a pair of clamps alone will generally suffice with asbestos patch.

Cracked Flanges.—If the crack is radial, as Fig. 141, a similar clamp to that of Fig. 140, fixed as shown, is the best repair. If a piece is broken out, as Figs. 142 and 143, destroying the hold of one bolt, a screw boiler clamp (Fig. 144) or

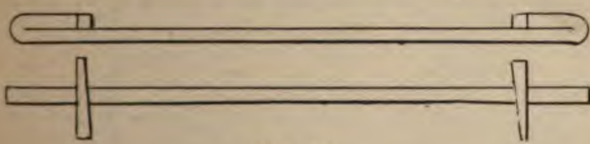


FIG. 147.

pair of plates and bolts may be used as shown; but such fracture could only occur with cast-iron flanges.

Broken bolts must be replaced with other bolts, the nearest ize available. A good way to make odd size bolts is to cut ff a piece of round iron, screw both ends, and run a nut on at ach end (Fig. 145). A piece of pipe and two pipe unions an be made to do duty for a temporary long bolt (Fig. 146); ometimes a long cramp and wedge can be used, as Fig. 147; iis can be promptly made from a piece of bar iron of any

section. Set-screws are made by screwing down a bolt of the proper diameter and cutting off the surplus screwed part. A broken set-screw is often difficult to extract, but can usually be driven round by a chisel-pointed punch (Fig. 148). Heating the part and using a little oil will make this easier.

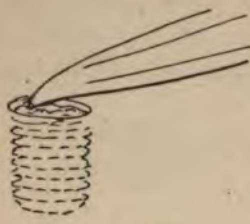


Fig. 148.

A broken shaft is a much more serious matter, and often impossible to repair at sea, but some very unpromising jobs of this kind have been overcome and may occur again. Such a fracture naturally occurs most frequently in the weakest part of the shaft, which is one of the journals; the best method of dealing with this is shown in Figs. 149 and 150. Remove the bearing entirely, cut two, three or more sunk key beds across the fracture and fit an equal number of pieces of bar iron or steel as keys; make three or four strong wrought-iron cramps in halves and bolt firmly on as shown, after which wedge up all the space between the keys with hard wood and iron or steel wedges. A temporary bearing can be built up as close as possible to the old one and steadied by wood struts from the nearest available fixed framing of the ship.

Fig. 149.

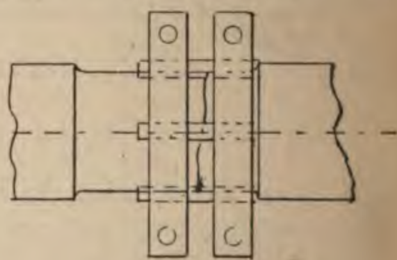


Fig. 150.

A screw shaft of the s.s. *Umbria*, broken in the thrust bearing, was temporarily repaired as in Fig. 151, by cutting notches in the flanges and using them to take bolts and nuts as shown. This plan would not be successful unless the fracture ran diagonally, as in this case, as the bolts would be

dragged round out of line and broken by the cross strain on their heads and nuts. In the latter case a sunk key or two would be necessary to take the torsional strain off the bolts. A fracture inside the stern tube could not possibly be repaired at sea.

Paddle-shaft fractures can be similarly repaired. Sometimes a crank arm breaks; in this case a wrought-iron strap,

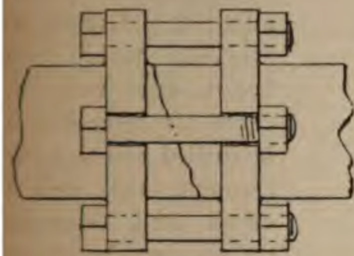


FIG. 151.

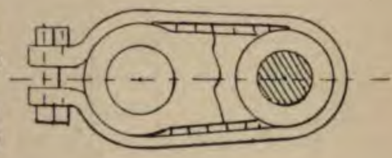


FIG. 152.

bent from a flat bar, can be fixed round and bolted, and wedged up as shown (Fig. 152); a strong bar will be needed for this job and a good bolt through the ends, as shown. A worse breakage is one through the crank pin; the most satisfactory repair for this is to drill a hole right through the centre line of the crank pin and drive through it a steel bolt

FIG. 153.

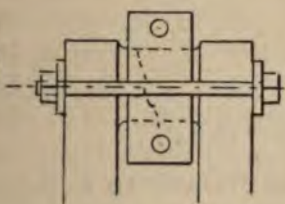


FIG. 154.

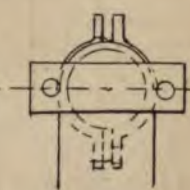


FIG. 155.

(Fig. 153). If the shaft is well supported endwise by its bearings it may run at reduced speed without any repair, keeping the connecting rod end well oiled. Otherwise the cylinder must be thrown out of action and a pair of clamps and temporary bolts fixed as in Figs. 154 and 155.

All these temporary rigs require constant watching, as

they loosen and are liable to give out from the vibration and strain; and it is very desirable to have spare bolts and plates ready to put on in case of failure.

A breakage in the crank journal (Fig. 156) is more difficult to deal with, as it generally happens that the bearing cannot be dispensed with, so that a rig on the principle of Figs. 154 and 155 cannot be employed. If this is so, one of two methods must be adopted. If there is screwing tackle on board, one, two or three set screws can be drilled and tapped through the crank cheek and through the fracture into the other end of the journal, as shown in Fig. 156. This is difficult to effect as drills of different lengths are needed, and in any case they cannot be longer than the width of the crank slot unless the shaft can be lifted out. Another plan is to fit sunk keys across the fracture, as in Fig. 157, and file them down to the curve of the journal, fastening them by screws tapped into the shaft.

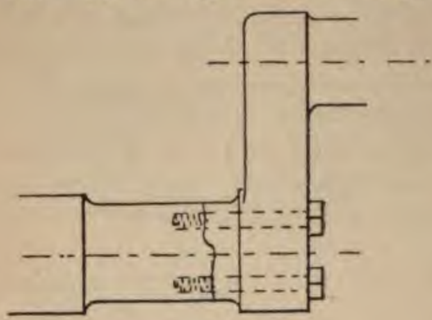


FIG. 156.

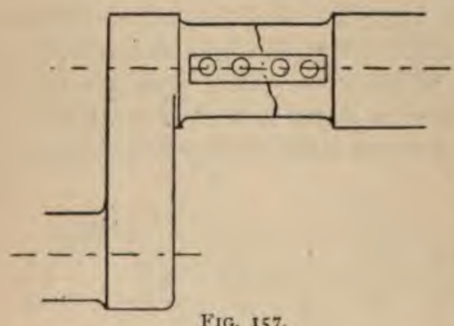


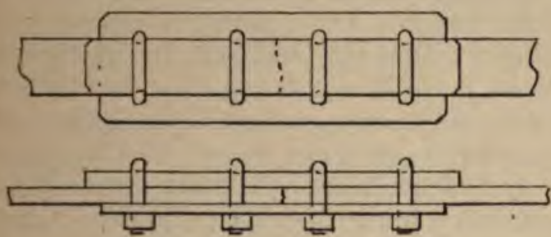
FIG. 157.

Paddle-wheel Breakages.—These generally occur in the arms, floats, centre pins and feathering rods; such repairs are not difficult to deal with except in a heavy sea. Flat arms can be spliced with two fish plates and bolts, but if possible should be welded up. When the broken arm cannot be taken out to drill or weld, staple bolts should be made and the splice fixed up as Figs. 158 and 159. Broken pins can

be replaced with spare ones, kept in stock, or a bolt and nut substituted. Broken rods should be welded if possible, or the ends may be screwed gas thread, and a piece of pipe tapped and screwed on to form a coupling; spare rods, centres and arms should always be kept ready for emergencies.

Propeller blades sometimes break off, and to lift the propeller and replace a blade is an arduous job in a sea way, but has been done. More generally the propeller has to run lame at reduced speed until port is reached, at the risk of damaging the screw shaft or the engines.

Numerous minor repairs to details of the engines and pipe work have to be dealt with on their merits: cocks ground in, valve spindles repaired or straightened, odd screws and bolts



FIGS. 158, 159.

replaced or refitted, broken studs drilled out and new ones fitted, &c., but whenever possible these are left to be done when the ship is in harbour.

Condensers.—There is considerable variety in the form and construction of these as now manufactured. There are (1) surface condensers; (2) jet condensers; (3) exhaust jet condensers; (4) gravity condensers; (5) air condensers.

Surface condensers condense the steam by water-cooled tubes; the water sometimes traverses the tubes and sometimes circulates around them. Jet condensers are simply circular vessels in which the entering steam is condensed by a spray jet of water drawn in by the vacuum. Exhaust jet condensers or ejector condensers are a modified form of injector in which the entering current of steam is carried forward with a current

of cold water and forms a vacuum, the force of the current being sufficient to discharge the condensed water and air. A gravity condenser is a modification of the jet condenser requiring a fall pipe 34 feet high to discharge the condensed water without an air pump. This is seldom possible, so that this form of condenser is very rarely used.

Air condensers consist of a large number of tubes enclosing the exhaust steam, and well exposed on their outer surface to the air; a large surface is thus required.

Condensing by Radiation.—Where other plans are not available this deserves trial. It consists of a number of pipes arranged horizontally, joined at their ends in the same way as a steam radiator, and interiorly connected to the exhaust. A small quantity of cooling water is allowed to trickle over these pipes from a perforated trough above, and a good vacuum can be thus maintained. The quantity of cooling water will seldom exceed that of the boiler feed, for which it may be used. An air pump is required to clear the condenser, and mud holes to remove scum and grease occasionally.

In applying a condenser to an existing engine the following circumstances must be taken into account:—(1) Amount of cooling water required; (2) position of condenser and mode of driving the air pump.

The amount of circulating or jet water required may be found by the following rule:—

q, quantity of water in cubic feet.
t, temperature of ditto.
Q, quantity of steam in cubic feet.
T, temperature of ditto.
t', temperature in the condenser.

$$q = \frac{1 \cdot 4\, Q\, (990 + T - t')}{V\, (t' - t)},$$

or may be taken at from 27 to 30 times the weight of steam condensed.

Upon the quantity available depends the possibility of using a condenser. Where only a pond or reservoir is at

ıd and the water must be used over again it is found that ırge pond surface is necessary, unless some artificial cooling ɔcess is resorted to. This may consist of a series of shallow ıys of wood or metal which drain by gravitation from one another, the last and lowest one delivering into the pond ;ain. A good example of this is a central elevated basin ʼerflowing down a series of terraces or shallow steps arranged round the central basin. Another plan recently used is to pray the hot water from the condenser into the air over a ›ond by pumping it through fountain jets.

The amount of water required does not vary much with either system of condensing, but assuming a plentiful supply, there are differences of level that are frequently of importance. A surface condenser must have the supply flow to it by gravitation or by a pump, and as the circulating water does not mix with the steam, the outlet must be low enough for it to flow away by gravitation or be pumped out. In a steamship this is done by a pump, which takes its supply from the sea and forces the water overboard again. A jet condenser may have its supply several feet below it, the vacuum in the condenser being sufficient to draw the injection water from o to 26 feet, but much less than this should be the source f supply, otherwise the jet will not be powerful enough to roperly spray the condenser, and in practice the higher the ıpply the better. In this condenser the whole of the water ıd air are drawn out and delivered at any level required ʼ the air pump. It is best, however, not to feed the boiler ɔm a jet condenser hot well, because the water contains ease and other contamination from the engines.

A surface condenser also requires an air pump—but of ıaller size—to discharge the air and condensed steam.

Ejector condensers should have the water supply on the me level as the condenser, but work with greater certainty th a head of 15 feet on the supply, and the discharge is ıde at a slightly lower level by gravitation, no air pump or culating pump being needed.

The gravity condenser requires the supply at the top d delivers the whole of the condensed water and air at a

point 34 feet lower down, no air or circulating pump being required. These condensers require about 100 gals. of injection water per I.H.P. per hour.

These points of difference are mentioned because an engineer is often called upon to fit a condenser to an existing engine or to set one right that does not give satisfactory results. The air pump (and circulating pump when one is necessary) are usually driven from the engine crank shaft but may in fact be fixed anywhere and driven anyhow, either from the shafting or by a steam donkey. The rules for the size of pump are very empirical; it is usual to make them too large, because this involves no loss beyond additional friction, as the surplus power goes to improve the vacuum. The usual rule for an air pump is one-eighth the capacity of the steam cylinder (in compound engines the capacity of the *low-pressure* cylinder must be taken). With a surface condenser this is reduced to about one-sixteenth. A jet condenser should have a capacity of from one-quarter to one-half that of the steam cylinder.

The area of the injection orifice should be in square inches about one-eleventh of the number of cubic feet of injection water supplied per minute.

The area of cooling surface in surface condensers should be one-half that of the heating surface of the boiler from which the steam is taken. The rules here given assume that the air pump is driven stroke for stroke with the steam cylinder.

Defects and Repairs.—Surface condensers are peculiarly liable to leakage at the tube joints, owing to the varying temperature and consequent expansion of the tubes. A good many plans are in use to obviate this, some of which are shown in Figs. 160, 161 and 162. Ordinarily the tubes are tightened by tapered expanders and ferrules driven in. A burst tube is often plugged for a time, pending a thorough repair. In other respects surface condensers give no trouble. Jet condensers rarely need repair. Air pumps, however, to both varieties,

FIG. 160.

often need new valves and sometimes reboring or relining, consequent upon pumping hot water, the temperature of which is sometimes 150°, but should not exceed 100° to maintain a good vacuum. The valves are usually in the piston and of the rubber disc type; the piston should have brass ring packing and the pump a brass lining; the pump

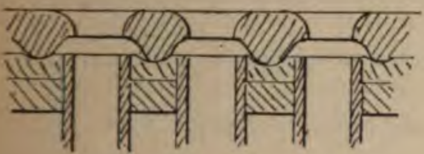


FIG. 161.

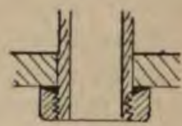


FIG. 162.

rod is also usually of brass or has a brass lining. The foot valve is of rubber, either circular or of the flap form.

In working, the pump lining and piston become grooved and worn; the rod also gets cut and grooved and reduced in diameter; the piston rings lose their elasticity and wear thin.

Relining Cylinder and Rod.—For small cylinders, drawn brass tube up to about 8 inches diameter can be obtained accurate enough to drive in. Large bores are fitted with cast brass liners, or with a bent plate metal liner brazed at the joint, bored and turned to fit and driven in by screws or bolts, taking care to force it in evenly or it will jam and get forced out of form. Rods can be lined with drawn tube. It is possible, but risky, to cast a liner on the rod, but is often a failure, owing to the difficulty of getting the rod hot enough when casting. All joints in connection with a condenser must of course be perfectly free from leakage; extremely minute leaks soon pull down the vacuum realised, and a vacuum gauge should always be fixed where it can be easily seen; it will show at a glance whether the condenser is working properly.

CHAPTER IX.

GAS ENGINES.

MR. CLERK divides these into three distinct types, viz.:—

1. Engines igniting at constant volume, but *without* previous compression.

2. Engines igniting at constant pressure, *with* previous compression.

3. Engines igniting at constant *volume with* previous compression.

The first is the ordinary non-compression engine, such as the old "Lenoir," the free piston "Otto and Langen," or atmospheric engine, now but little used, and the "Bisschop" small power engine, still in use for many light purposes; but the principle of non-compression is out of date entirely now, being too wasteful in gas.

The second and third types of compression engines include the "Otto," and its numerous imitators, the "Clerk" engine, "Tangye's," the "Stockport," the "Atkinson" and others.

These engines vary in the cycle of work done in the cylinder, some giving an explosive impulse every revolution, others an impulse every other revolution; these are termed respectively, two-cycle and four-cycle engines. Compared with the steam engine, the gas engine is undoubtedly more efficient in converting heat into work; the heat efficiency of the best steam engines is not more than ·10, while gas engines of the first and second types develop from ·06 to ·08, and those of the third type as much as ·17, the highest recorded being ·25.

But mechanically considered, the gas engine is far inferior to the steam engine; many of the defects, however, are gradually being eliminated, and it will probably soon rival its predecessor. At present it is not easily managed for higher powers than say 12 horse-power, though very much larger engines exist. This is chiefly due to its mechanical defects.

The oil engine is simply a gas engine with an oil-spray gas-generator attached (see p. 183).

The defects of this class of engine are :—

1. Loss of heat through insufficient expansion of the gases.

2. Great loss of heat through the water-jacket, amounting to nearly 50 per cent. of the total heat supplied.

3. Loss of heat from exhausting at high temperature—about 15 per cent.

4. Loss from unburnt gas escaping into the exhaust.

5. High temperature of combustion, and consequent dry and hot condition of cylinder and piston, requiring constant lubrication.

6. Intermittent impulses.

7. Heavy fly-wheel necessary to regulate the motion.

8. Water jacket, tank and connections, and the increased trouble, cost and space they require.

9. Difficult lubrication.

10. High speed of revolution necessary, and lack of power to run at varying speeds or to be reversed.

11. Difficulties of starting.

12. Wear and renewal of slide faces, or of igniting tubes; difficult ignition.

13. Choking of ports and exhaust with soot, oil and corrosion.

14. Noisy action.

15. Great size of engine compared with the power developed.

This seems a fair catalogue of demerits, and though efforts are being made to reduce them, at present the gas engine is a prolific source of trouble to the repairer, and equally so in maintenance by the user.

Its advantages, however, are so great as to entirely outweigh its defects, for many purposes, and in fact, many small industries are absolutely dependent on it. Among these advantages the chief may be considered its capability of being started at a minute's notice, and stopped by simply turning off a tap or two; absence of boiler, fire or steam; and the small amount of attention required when running.

Our traditions and experience of the steam engine are of little service in dealing with gas engines, though they seem to greatly resemble one another externally. A steam engine would run, and give fairly good results, many years after a gas engine, in a similar condition as to wear and tear, had ceased to work at all; and it becomes necessary, with the gas engine, to be acquainted with the details and principles of every type in use, its cycle and valve arrangements.

Following our plan adopted in detailing steam engine repairing, we will dissect the engine generally, and then refer to those types which need special treatment, for with gas and oil engines the differences of principle and details are so great that no general description will suffice to enable an engineer to deal with the numerous varieties extant, and in this class of motors considerable experience is necessary to cope with their faults.

The cylinder becomes worn in that part of the bore traversed by the rings, and differs from the steam cylinder in the fact that this wearing part is only a part of the entire bore; there is no bell mouth possible at each end of the working bore, and consequently, when worn it must be rebored, or, more generally, a new liner inserted. Gas engine cylinders are usually fitted with a liner, which, by fitting at each end to the outer case, forms a water space for cold water circulation, and, compared with a steam cylinder, a very moderate amount of wear necessitates renewal. If rebored, the piston, which is of the ram form, would be too small to serve as a guide, and thus a new one would be needed. Horizontal cylinders wear oval, vertical cylinders slightly so, and both wear deeper in the middle of the working bore than at the ends. Inefficient lubrication or the use of inferior oil will quickly cause wear and corrosion of cylinder, piston and rings, as also any leakage of water from the jacket, which sometimes occurs. A very hard scale or grit forms on the surface of the combustion chamber at the back end of the cylinder, and care must be taken not to leave any of it loose in the cylinder, or it will cut the bore and rings and choke the exhaust valve. The water jacket in course of time often gets filled, or nearly so, with sediment

and corrosion, which also choke the circulating pipes. It can only be cleared from round the cylinder by taking out the liner.

The piston and rings require the utmost care in fitting to the bore of the cylinder. At least three rings are usually supplied, with loose junk rings between them. New rings can always be obtained from the makers of the engines. It is not sufficient to simply turn these rings true, split them and place them in the piston, they must be tried in the bore, and the lumps eased down with file and scraper, and marked to go into the piston in the position they have been fitted. Endwise they should fit the junk rings so that they have only sufficient freedom to expand and contract, and the faces or joints A towards the combustion chamber scraped to a good

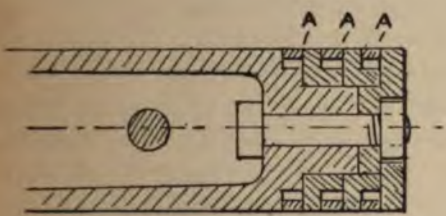


FIG. 163.

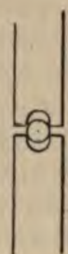


FIG. 164.

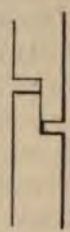


FIG. 165.

fit to the junk rings, Fig. 163. The rings are ordinarily simply split with a stop or pin between the joint, as Fig. 164; but would be much better lapped, as Fig. 165, as the very smallest leakage past the piston, especially in small engines, destroys the power of the engine. It must be remembered in explanation of this fact, that in the gas engine the impulse given is, in effect, a blow, followed by a push, much like that of a hammer, the effect of the blow acting only throughout one stroke out of four; then the piston runs three strokes without any impulse at all, so that all retarding forces and the compression stroke have to be taken out of the one blow received in four strokes. The explosion is sudden, and the pressure momentarily attained, high, sometimes 190 lbs. per square inch, which requires absolute

air-tightness to prevent great loss by leakage. There are at least two other possible sources of leakage besides the piston, that is, by the slide and by the exhaust valve. This is the most serious difficulty with the gas engine, viz. air-tightness combined with freedom of movement. First-class workmanship is absolutely necessary in the working parts. It often happens that when new rings are fitted the engine will not move at all, or works very feebly; this generally arises from the rings imperfectly fitting the bore; the old ones had worn to a fit, but becoming weak allowed the gases to escape past them. This leakage can generally be seen by smoke coming from the front of cylinder, or it may be tested by a light, which will fire the leakage gases in front of the piston. The slide is a cast-iron double-faced slab, with ports cast and drilled in it, and works between a false face or seating screwed to the cylinder, and a loose back plate, to which latter pressure is applied by springs with regulating hand nuts. It serves to distribute the gas and air, and carry the flame of the pilot light to the igniting port, but does not regulate the gas supply nor discharge the exhaust gases; there are separate spindle valves for these purposes. Great accuracy is required in the positions of the ports and the slide. The false cylinder face and the back plate must be very accurately scraped, leaving the cut-off edges of the ports higher than other parts, and the less important parts of the faces relieved back or scraped low. The engine makers supply diagrams (see p. 152) to assist the fitter in working up these faces with accuracy. A very good surface plate is necessary for this job. The oil grooves A A must be kept open; the pressure applied to the slide must be even, and such that it does not lift, however slightly, from the face when explosions occur, or it will blow out the pilot light—nor so heavy as to make it hard to move. An important point is an even thickness throughout the slide to be tested by callipers. Badly cut slides must be carefully planed with a smooth tool before scraping, taking off as little metal as possible, and cutting back the low parts unshaded at the ends of the slide so that they do not touch at all. The ports must be kept clear of

soot, especially the small drilled holes. The small hole D feeds the flame in the hollow E, by a supply of mixed gas and air from the charge in the cylinder just before it opens to the cylinder port to fire the charge.

The pilot jet is in the back plate, Fig. 174, p. 153, and kept steady by a chimney; being very small it is easily choked with soot, dirt or scale from the chimney The gas for supplying it ought to be taken from some other source than the engine service-pipe, as otherwise the intermittent draught on the pipe will frequently check the pilot service so as to put out the light or make it jump. The inner jet in the slide is fed by the small port F, from the back-plate, and as it is generally blown out at each explosion, the function of the pilot light is to relight it. Both jets can be regulated by thumb screws. The main cock should be fully open, and the jets turned down to the size of a large candle flame.

Gas Supply.—The pressure of gas in all towns varies during the twenty-four hours; more pressure is put on during the evening hours, and is again reduced after 11 or 12 P.M.; but notwithstanding this the greatly increased consumption in the evening often reduces the actual pressure below that of the daytime, owing to the gas mains being too small. It often happens thus, that an engine set to run correctly by day will not run in the evening, or *vice versâ*, because of the varying pressure; and the graduated gas main cock has to be altered to suit the variations of pressure. This is often a troublesome fault. It is certainly a mistake to depend upon regulation of cocks under such varying conditions for measuring the due proportion of gas to air. It is further complicated by the irregular demand the engine makes when running under varying loads, for which kind of service, in fact, the gas engine is particularly useful. Pumping water for lifts, driving printing machines, hoists and similar work entails very varying demands on the gas supply. This difficulty does not occur with oil engines, in which the supply of oil is regulated by the governor, and hence with oil engines the supply of gas depends solely on the governor.

The gas bag is intended to act as a reservoir, receiving on

its inlet side a constant supply of gas, and delivering at its outlet side small charges at uncertain intervals, regulated by the engine governor; but very fine adjustment of the main cock is often needed to correctly regulate the pressure in the bag, and this cock should always have a graduated sector plate for this purpose. It is necessary frequently to further adjust the gas supply at the engine gas cock, though this is intended to be either fully open or shut. After passing this cock the gas has to pass a small spindle valve opened by the governor and closed by a spring. If this fails to seat properly the engine will run away by taking gas at every revolution. This is a faulty plan and ought to be replaced by a valve with a positive motion. The whole of this uncertainty and finicking adjustment might be avoided by measuring in the quantity of gas by a small pump. In the hands of unskilled, and, in fact, skilled workmen too, this gas supply causes endless trouble, the results being often set down to every cause but the right one.

Air Supply.—There is no regulation to the air supply, but some engines provide apparatus to baffle it in various ways to avoid the sucking noise which always accompanies it, and various attempts have been made to heat it from the waste heat of the exhaust.

Exhaust.—The exhaust valve is always of the spindle type, generally forged of hard steel, with a steel or wrought-iron seating. It is exposed to great heat from the products of combustion in the cylinder. Water is sometimes circulated round its seating to cool it. Bits of scale and soot are apt to get between the seating and valve, and either partially or wholly stop the engine by causing leakage and preventing proper compression. This can always be felt by the lack of resistance on the compression stroke when pulling the engine round by hand. This valve is therefore made to take out easily, and must be frequently cleaned.

At intervals it will have to be turned and ground in afresh with flour emery and oil. The method of opening it by a pushing action from a lever is bad, as it causes the guide to wear oval, and makes the valve loose on its seat.

The governor acts by cutting off gas entirely when running

too fast, not by gradually reducing the supply as in the steam engine, so that a "hit and miss" gear is employed, some forms of which are simple and very ingenious; in fact this is the most satisfactory part of the mechanism. Between the explosion charges, therefore, the engine takes air only; and if the gas supply has been properly adjusted and the governor acts properly, each explosion charge will have an equal quantity of gas in it.

The Water Supply.—Water is circulated by natural flow round the hot part of the cylinder to keep its temperature within working limits, also sometimes round the exhaust valve and the slide. A large water vessel is fixed at any convenient point, which should be at a rather higher level than the engine, and a flow pipe led from the top of the cylinder jacket to the top of the water vessel, also a return pipe from the bottom of the water vessel to the bottom of the cylinder jacket. The pipes and vessel should be galvanised, and the pipes not less than 1-inch bore; the larger the better, as they get choked with sediment. Sometimes the engine bed is used as a water tank for this purpose. The water vessel or tank must be kept full by a ball cock; the pipes should have a slope upward from the engine, and the joints should be flanged; it is desirable to have a cock in each pipe so that they can be shut off when repairs are needed to the engine; in any case an emptying cock must be placed on the lowest part of the system. When water is circulated through the slide it is done by rubber pipes with stop cocks to shut off the water when the slide has to be taken out. The heated water ascends the flow pipe from the cylinder to the top of the water vessel, and as it cools it sinks and returns to the bottom of the cylinder by the return pipe.

Foundations.—A good foundation is as good an acquisition to a gas engine as to any other engine, by giving solidity and preventing vibration, but it is frequently fixed on any available floor without much preparation. On a wood floor it becomes noisy: the floor, acting as a drum, reinforces the normal noisiness of the engine. Several thick layers of felt will reduce this to some extent. These should be laid

between a wooden frame under the engine bed and the floor. Where quiet is essential the engine will do best on a solid *independent* foundation in the basement, or some remote part of the building, and may further be enclosed in a brick-built room *not connected to the main building* in any way.

If required to be fixed in an upper floor and free from noise, the best plan is shown in Fig. 166, where the engine stands on felt and is bolted down to iron girders and concrete, supported independently of the floor; the girders may be let into a main wall at each end, or rest on the floor at their ends close to a main wall. On an ordinary wood floor the engine should stand on a wood frame the shape of the bed and a little larger all round. The foundation bolts must either go through some of the joists or through blocks fixed between them, with large washers under the heads. On a stone-paved or concrete floor no preparation is needed except cutting holes for the foundation bolts, which may be run with sulphur or neat cement, and cement laid under the edge of the engine bed, with a few wedges to keep it steady while the cement is setting.

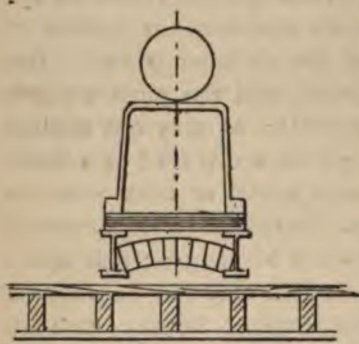


FIG. 166.

With a brick or earth floor it is best to cut out a rectangular bed and fill with concrete from 9 inches to 24 inches deep, according to size of engine.

Running gear, consisting of connecting rod, crank shaft, side shaft, &c. These are essentially the same as in the steam engine and are treated in the same way. The side shaft is commonly driven by screw or single helical gear in lieu of bevel gear, as being less noisy, though the latter is still sometimes used. The gear is enclosed in a guard box of cast iron, and requires good lubrication and usually works well; sometimes, however, a tooth will get broken, when either a new wheel must be fixed or a new tooth (see Chapter XIX.). The

ıeels and, in fact, all other parts are usually stocked by the akers, and are interchangeable. When ungearing these ıeels for any purpose, see that they are properly marked on e teeth so that they may be put together correctly again, or ıe engine will not work.

Lubrication is a very important matter. Automatic lubriators, many of them very ingenious, are invariably used to eliver oil regularly—according to the speed of the engine—o the cylinder and the slide; failure of the oil feed from any ause quickly causes damage to both cylinder and slide. Other parts of the running gear are fed by oil-can in the usual way. A good quality of oil is absolutely necessary to prevent choking of ports, gumming and other difficulties. The lubricators should be filled every morning and their working examined, oil tubes kept clean and their actual delivery of oil noted to both cylinder and slide valve.

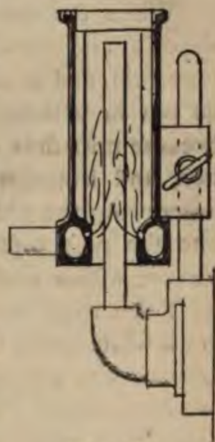


Fig. 167.

The oil used should be a mineral oil of good body; vegetable and animal oils are bad because they leave a good deal of deposit in the combustion chamber and exhaust; gas engine makers insist on the use of a first class oil, and in ome cases supply special oil for this purose.

Tube ignition is rapidly replacing the slide in all types f engines. It is simpler and generally more reliable.

A metal tube (Fig. 167) closed at one end and open to the linder at the other, is heated to a bright red heat by a ınsen flame, and at the proper moment the compressed xture is allowed to enter the tube, where it is instantly ıited. It is only possible with compression engines, as nsiderable pressure is necessary to force the gases into a ısed tube.

It is necessary that the burner give a good flame so as to at the tube to more than a red heat, to fire the gas with

certainty. In some engines the time of firing can be regulated by raising or lowering the flame round the tube, so as to heat it further from or nearer to the cylinder; in others a timing valve is used which opens by gear and admits the compressed gases into the firing tube at the right point in the stroke; the first method is shown in Fig. 167. Wrought-iron tubes, lasting only two or three days, have been generally used, but several new forms of tubes are now made that will last many months. All tubes should fit in a cap or screwed head, to enable them to be easily removed and new ones inserted. The chimney must be lined with one or two thicknesses of asbestos millboard.

When the tubes begin to leak or become choked with deposit and oxidation the firing becomes irregular and uncertain, and as soon as this is noticed a new tube should be put in without waiting for the old one to finally burst, because miss-fires cause great increase in the gas consumption, and irregular action and thumping of the engine. In unscrewing the old tube see that no scale or grit gets down into the port below. In some engines these ports can be cleaned with a wire by unscrewing a small plug.

Tubes may be overheated; the proper heat is a bright red, not a white heat; if overheated they will burst and may hurt any one who happens to be looking on. The Bunsen burner requires careful adjustment to burn without any tongues of flame, and without lighting back to the air inlet as it will sometimes do. Currents of cold air will also prevent it burning steadily. After starting, as a rule the Bunsen flame can be reduced, as the heat of the explosions inside the tube keeps it hot.

Timing valves are now becoming general with tube ignition; it is important that the full effect of the explosion should act at the proper position of the crank, to avoid loss of useful effort. They are generally operated by a lever from the side shaft, and have means of adjustment to suit the required angular position of the crank. These valves are of course liable to leak through becoming scored or burnt by the heat, and then can be ground in with fine emery and oil,

and should be tested by blowing through before putting in again. One of these valves is shown in Fig. 179, p. 159.

Compression is rightly considered as the chief source of gas engine economy. Weaker mixtures can be fired with compression than without it, and the initial pressure of explosion is much greater than is due merely to the added mechanical compression; the expansion is more effective and the total power of the engine largely increased. Loss of compression through leakages is therefore a serious difficulty, and may even stop the engine when running light; but compression necessitates an absolutely tight cylinder and piston. The effectiveness of it can always be felt by pulling the engine round by hand, and any loss of resistance must be at once traced to the valves or the piston.

Detection of faults is no easy matter in a gas engine, there are so many points which may cause similar symptoms. Assuming that an engine has stopped from some cause unknown, and cannot be started, proceed as follows:—

1. See that the gas supply is all right, and the main cock and cylinder cock open, also that the governor gas valve lifts and closes properly. If any doubt exists, disconnect the pipe from the engine cock to see if water has choked it anywhere.

2. Try the slide and pilot lights and adjust them.

3. See if the engine moves freely, that the pressure on the back slide plate is evenly adjusted, and that it is well oiled.

4. Before putting on gas try the engine round with air only, noting the amount of compression by the resistance or recoil if let go when on the compression stroke. If this is faulty it is leaking either at the exhaust valve, round the piston, or at the slide.

To prove these points, examine the exhaust valve first, clean it, give it a few rubbings round with oil and replace it. If scored on the seating ring it must be ground in again; if there is no improvement take off the slide; if the faces are bad this may account for the leakage. Either reface them or put in the spare set, if they have been

faced ready, as they always should be. Cases occur where the leak is found to be under the false face screwed to the cylinder, and occurs either from permanent distortion of the plate by the heat, or from having been screwed down with grit between the joint; such leakage shows itself invariably as a dry burnt patch on the plate. Any leakage remaining now must be past the piston.

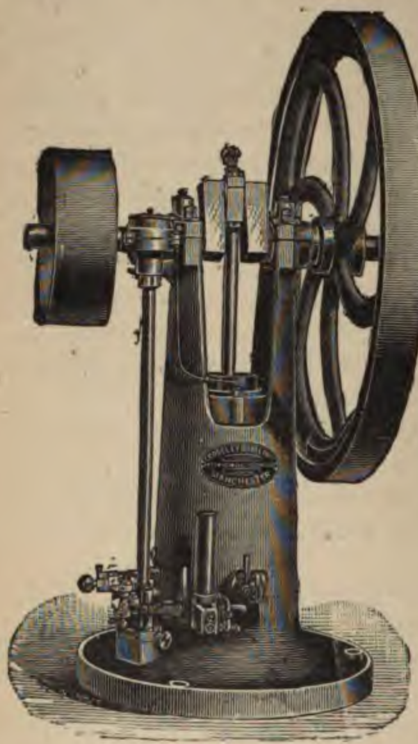


FIG. 168.

5. If now it is found that the explosions take place regularly, but that the engine will scarcely run even with no load on, it must be due to leakage round the piston.

This can be proved by putting the gas on and pulling the engine round, holding a light at the mouth of the cylinder; escaped gases will be inflamed.

Frequently the difficulty of obtaining proper explosions at starting is simply from too much or too little gas. Try a start with the gas bag half full, then three-fourths full, and so on until an explosion is obtained, when the main cock should be instantly opened to the usual mark at which the engine runs.

It will be found in starting that, with the gas bag full and the main cock closed, the first two or three charges rarely explode; that is because too much gas is drawn in when the bag is full. If after the first one or two explosions no more

can be obtained, the cause is again either too much or too little gas (unless the pilot light has been blown out or is too low), and another trial should be made admitting first *less* gas, and if unsuccessful, *more* gas than was first tried after the initial explosion. Hours are frequently spent in this fumbling process, simply because there is no certain and reliable gas supply, and it frequently happens that when the happy medium has been found it is difficult to hit a second time.

The "Otto" Gas Engine, and others with the "Otto" or

Fig. 169.

four-cycle. Except in the case of large engines and those with self-starters the foregoing notes apply fully to this class. Fig. 168 shows the vertical type of this engine by Messrs. Crossley Bros., Limited, and Fig. 169 the horizontal type.

Vertical engines of this type are made up to 1½ H.P. but do not differ materially in detail from the horizontal form; and double cylinder engines are made indicating as much as 170 H.P., while much larger engines are contemplated.

The following instructions are issued with these engines

by the makers, Messrs. Crossley Bros., Limited, Openshaw, Manchester:—

Before starting.—Having seen that everything is clean, both inside and outside, that the water is properly supplied to the cylinder jacket, and that the moving parts are all free and well oiled, especially the slide valve, first light the burner at bottom of chimney and adjust the inner light, which will be right if turned as high as possible without causing it to smoke.

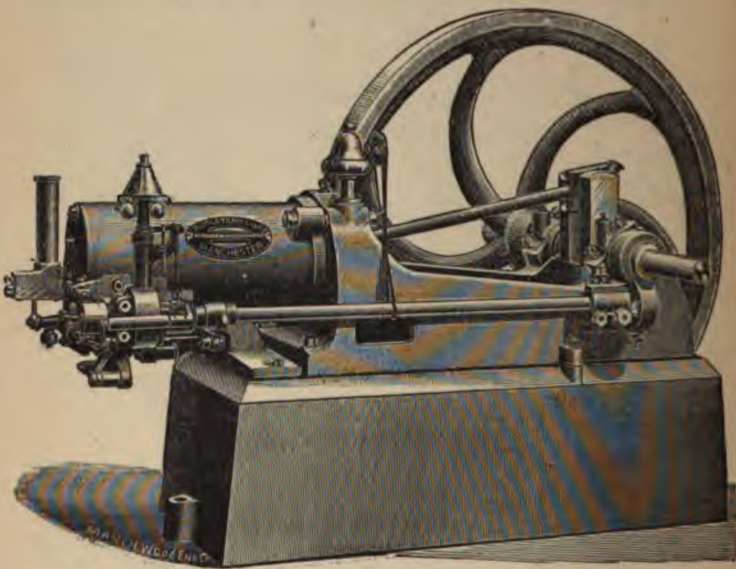


FIG. 170.—CROSSLEY'S "OTTO" GAS ENGINE, 4, 7, 9 AND 10 H.P. DESIGN.

The governor.—Next move the governor to its middle position, and fix it there by means of the "stop" provided for this purpose, so that it can act upon the gas valve. The "stop" should disengage itself as soon as the engine begins to run.

Functions of the governor.—The governor performs two distinct functions. It cuts off the gas both when the proper speed is exceeded and also when the engine stops. See that these are properly performed, and that the gas valve shuts correctly, lest "running away," or waste of gas accidentally follow.

Adjusting the slide valve.—To adjust the slide cover, slacken the

ll screws in the split stops behind the springs on the back of :r. Then screw up the springs by means of the milled nuts. :t screw up the small nuts on the stops moderately tight with rt spanner provided, and having afterwards released the springs, slide will be ready.

How to turn the fly-wheel easily.—To facilitate turning the engine hand at starting, the roller on the exhaust valve lever may be ed further out, so as to engage the second cam on the shaft, the that secures it being changed to the other side of the roller for moment; but when the engine has started the roller must be ired again so as to be moved by one cam only as before. In the ical type of engines the exhaust roller is lifted upwards, and held e by the taper pin whilst starting; when started, the pin is pulled and the roller drops into its working position. This remark does apply to the ½-H.P. size, which does not require a relief cam. there be nearly one-eighth play between this roller and the body am, when not lifting, to insure the shutting of exhaust valve.

Starting.—To prevent too much gas being given while turning ly by hand at starting (which often prevents ignition), close the behind the bag until the engine begins to work. Having lastly ied the engine gas cock, turn the fly-wheel immediately and kly a few times by hand, when the engine will at once begin to :. In engines provided with gas pressure regulators, the cock reen gas bag and gas main need not be shut for starting.

Lubricating.—The two principal parts requiring lubrication are slide valve and the piston. Self-acting oilers are provided for . These should deliver about four to twelve drops a minute to :ylinder, according to size of engine, and two to the valve. See they drop the oil as intended, as if allowed to run dry the sur- s will "cut" and the valve will require to be "faced," or the icate valve, &c., put on, before the engine will work again. Oil he other bearings three or four times a day in the usual way, and that none get warm from being too tight or too dry.

Sort of oil to use.—We advise the use of Price's Patent Candle s No. 272 B, which our experience proves to be of the most ible kind. Inferior oils always lead to difficulty from dirt left in ider and ports.

Cleaning slide.—Take out the slide valve and clean all the ages as often as any deposit of soot makes regular ignition :ult. Especially clean the mouth of the small hole marked A on

drawing, at which the inner light burns. If proper care is taken in not letting the lights burn too high so as to smoke, they may not need to be cleaned more than once a week. Small cleaning tools sent with engines.

Irregular working or stopping.—If the engine should stop or take long to start without apparent reason, examine the exhaust valve, ascertaining whether any dirt or other cause prevents its closing tightly, and if so, grind it in slightly by turning round with a little

OUTSIDE FACE OF VALVE

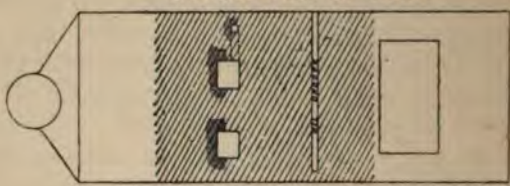


FIG. 171.

emery; and in replacing it, make the joints in the same way as previously. If this valve is not at fault, look to the gas supplies at every point, and see if the slide-valve is clean. Sometimes water, by accumulating in the exhaust pipe, may cause stoppage; a small hole or a tap at the lowest point of this pipe will prevent this.

Difficult starting, injured slide valve and other causes of irregular working.—Difficulty in starting will occur after a time from slight

INSIDE FACE OF VALVE.

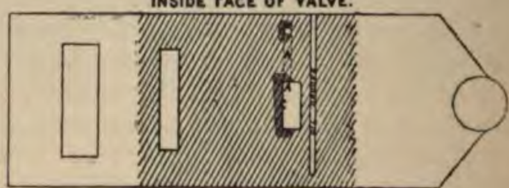


FIG. 172.

wear of the surfaces of the slide valve. This is easily rectified by a little filing or scraping down of the high parts (see Figs. 171–174). The duplicate set sent with the engine may meantime be used if desired, or in case of injury from want of oiling use the duplicates till repair is made. In putting these duplicates on the engine be careful to clean out the tallow and white lead, especially in the small vertical hole marked A on drawing, which is usually neglected, being difficult to see.

Gas bags should be carefully handled, being spoiled by oily hands. ;y should be so placed that oil cannot be thrown on them by the ine. Pipes must be properly screwed to the connections on the bag.

Defective gas fittings, jumping of gas-lights.—The gear which opens gas valve may also, after a time, wear a little, and thus decrease supply and cause stoppage; if it is easily adjusted. Also, the all gas-pipes which supply the le lights must not be connected h the principal pipe, or these y burn too unsteadily to ignite ;ularly. Supply them separately m another main, or use one of r Antifluctuators. This latter l also prevent all jumping of gas-lights sometimes caused by the gine.

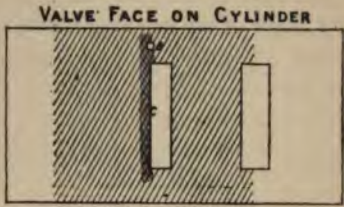


FIG. 173.

Cleaning the cylinder, adjusting the piston.—The piston should not taken out unless cleaning or new packing rings are needed; when is taken out scrape everything thoroughly out that may be left at e back, but if the oil and s are good nothing will found. The crank pin ass has alone to be un- upled to draw the piston. s it is also of primary portance that the pis- n should not leak, it is constructed as to be pable of the most perfect justment. The joints of the rings should be at e bottom side of the ton, and the rings should the grooves sideways as htly as free movement permits. The "junk ring" is easily adjusted the latter purpose. To draw the piston is easy; to put it back m it upside down, and when in cylinder turn it round so as to ing the figures on connecting rod to the top. Be careful to see at the small steady pins in piston ring grooves fit into the slots in e rings, or the rings will get broken.

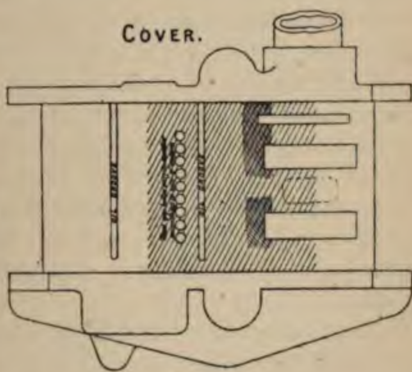


FIG. 174.

16-H.P. Engines.—In 16-H.P. engines the cylinder should be cleaned out inside once a week, not by removing piston, but by scraping the dirt out through the cover over exhaust valve, which is made large enough to admit a youth's arm.

Consumption of gas.—Regular working requires a certain proportion of gas to air. To see if this is correct watch the movement of the finger of the gas meter, and count at the same time the explosions when the engine is working full power. The following are the number of explosions per cubic foot of gas that should be taken by the various sizes of engines:—

20 H.P.	makes	4½	explosions	per foot.
16 H.P.	,,	5½	,,	,,
14 H.P.	,,	7½	,,	,,
12 H.P.	,,	10	,,	,,
9 H.P.	,,	12	,,	,,
8 H.P.	,,	15	,,	,,
7 H.P.	,,	17	,,	,,
6 H.P. Twin		17	,,	,,
6 H.P.	makes	19	,,	,,
4 H.P. Twin		32	,,	,,
4 H.P.	makes	32	explosions	per foot.
3½ H.P.	,,	38	,,	,,
2 H.P.	,,	55	,,	,,
1½ H.P.	,,	75	,,	,,
1 H.P.	,,	95	,,	,,
¾ H.P.	,,	110	,,	,,
½ H.P.	,,	120	,,	,,
½ H.P. Vert.		120	,,	,,
5 Man	makes	180	,,	,,

One explosion occurs after each lift of the small gas valve. When full gas is used the engines indicate much beyond their nominal power—a 16-horse indicating up to say 40-horse, and others as stated in prospectus.

Regularity of ignitions.—Always see that an ignition occurs each time the small gas valve is opened by the governor. If it does not, the cause may be dirt in the slide ports, or want of proper regulation of the slide lights, or wear of the slide valve. See "Difficult Starting," "Consumption of Gas," and other directions as above.

Water vessel and cooling.—Never work the engine without water in the jacket of the cylinder. The water vessel must be kept full by a ball tap.

Frost.—See that the circulating pipes are acting. The pipe from top of cylinder to water vessel should slope upwards at every point, being nowhere exactly horizontal or sloping down. The cylinder should not get very much hotter than the upper part of water vessel. If the engine is exposed to frost while not working, arrangements for burning a gas-light beneath the cylinder, to keep the water from freezing, should be made, or the cylinder may be emptied.

Erection.—For the arrangement of pipes, size of same, and size of gas meter, also for foundation and all other necessary particulars for erecting, see lithograph foundation drawing, sent with each engine.

xhaust pipe.—Never turn the exhaust pipe into a flue, or ney, or drain, lest an accumulation of gas in such may accilly take place, and damage be consequently done. Lead it to pen air through a pipe. The exhaust pipe must always be kept of timber work by 6 to 10 inches, according to size of engine. rge engines this is most important, as it sometimes gets very hot.

Construction of slide valve.—A small hole (marked B on drawing, 178) in the valve-face on cylinder connects the gas in the cylinder the gas in the lighting port of slide $\frac{1}{16}$ of an inch in advance he connection of the main port with the slide light chamber. If ir is required, this dimension must not be altered, nor any other he ports.

Dust.—Like most good machinery the engine must be thoroughly tected from dust or dirt, taking particular care that no dirt can on slide from roof or ceiling.

Spur wheels.—A printed label is attached to the spur wheels cting mechanics in erecting the engine to gear the tooth in bevil el marked O with the space in pinion O; mistakes are often made utting these wheels together.

Refacing valve, &c., see Figs. 171–174.

The movement of the valve of course tends to wear it hollow in middle of all the faces just where it must be kept high.

The unshaded ends must therefore be occasionally eased down a smooth file and scraper, say once in six months, or when gular ignition makes it necessary. This is easily done with the of a "surface plate," but accuracy is necessary.

The parts lightly shaded are required to touch thoroughly.

The smaller portions shaded darker should be highest, otherwise lar ignition will not take place.

If the slide bears hard on any of the unshaded parts, it may cause sing or irregular ignition by keeping the shaded parts from ciently close contact.

Keep the corners or edges C C, Figs. 172 and 173, sharp and high, rounded with the scraper.

Should cutting or galling take place, carefully attend to these ructions in re-surfacing, or put on the duplicates and return the rs for repair.

See that the small holes A A, in the valve, and B, in the valve , are clean. This is very important, the latter goes through into cylinder.

Stockport Engines.—These were, until recently, constructed with two cylinders opposite each other, the two pistons being in one piece, with the connecting rod connection near the base of one piston, and a single crank running in the space formed by removal of one side of the piston casting in the middle between the cylinders. Fig. 175 is an outline section of this engine. Air and gas are drawn into the pump and delivered along a passage in the engine bed to the working cylinder, which gives an explosion at every revolution. This, therefore, is a two-cycle engine. The earliest engines have two slides, one to admit gas and air to the pump, the other to regulate the admission to the working cylinder and control the firing. The diagram from the working cylinder and air pump is shown (Fig. 176). It was found that with a worn main slide or any leakage past it, the burning charge fired the whole of the gas and air in the passage and pump, causing a violent explosion which, if it did no damage, was very alarming, and this in spite of a nest of wire gauzes inserted in the port under the main slide. To obviate these back explosions—which of course stopped the engine—a check valve and set of gauzes was interposed in the passage,

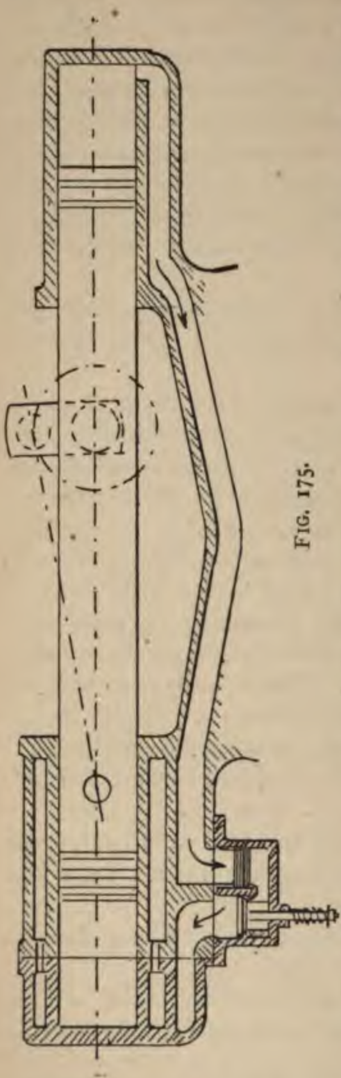


FIG. 175.

nd the valve was opened by the pressure of the charge of ases and closed by a spring, as shown in the section. There was no exhaust valve in this engine; the exhaust passed ut at a port uncovered y the piston at the nd of its out stroke. The slide ignition was imilar to the "Otto," ut the pilot light was ndifferently fixed in nany of these engines

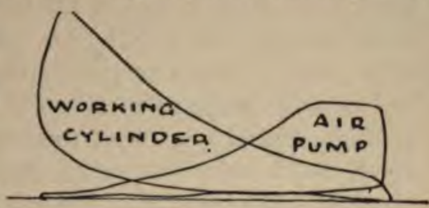


FIG. 176.

f the old types, so that it was liable to get a little to one side nd thus fail to ignite the slide light. No particular trouble as experienced with the pump or its slide, as they were cool n working, but the usual difficulties existed with the working ylinder and main slide as have been referred to (p. 138).

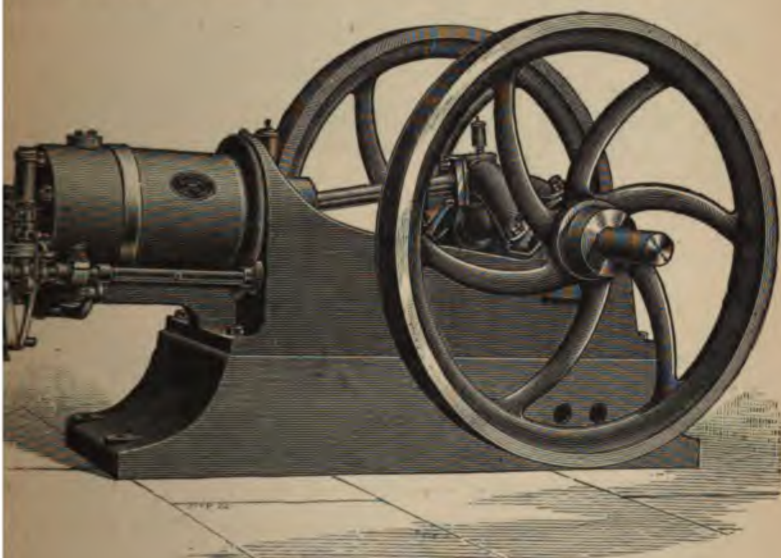


FIG. 177.

This engine has since been converted to the Otto or four-ycle principle, and now appears as Fig. 177, which shows ne engine in perspective. The design is very neat and the

construction throughout good, as the result of long experience with this type of engine. The cylinder, shown partly in section in Fig. 178, has a ram piston as usual, and the combustion chamber is bolted up as a back cover, with water circulation all round. The air, gas and exhaust valves are all of the mushroom or spindle class, and operated by levers and cams from the usual side shaft, which is driven by screw or single helical gear from the crank shaft; there is no slide valve, and these spindle valves give less trouble than slides and are more easily refitted. The ignition is by hot tube, but in

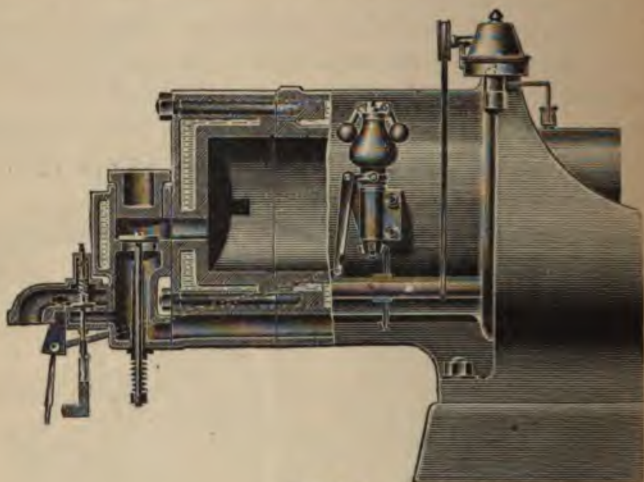


FIG. 178.

the new engine a "timing" or firing valve is employed, shown in Fig. 179, and in greater detail on p. 196, by which the exact moment of firing is capable of adjustment. Much loss of power results from premature or late ignition by reducing the effective mean pressure on the piston, which should receive its impulse when the crank has turned about 15° on the out stroke. The governor and oil feed are also driven direct from the side shaft. The governor is of the "Porter" type, and actuates the usual "hit and miss" movement at the end of the gas valve lever to admit or cut off the gas.

This engine has a very simple self starter, which is described on p. 196.

Our general notes on repairing, pp. 138–148, will be applicable equally to this engine, excepting such notes as apply to the slide gear.

The following instructions are issued by the makers of the new Stockport gas engines, Messrs. J. E. H. Andrew & Co., Limited, Reddish, and may be read in conjunction with our general notes above.

This engine is supplied with patent tubes which last some months in use.

Oiling the engine before first starting.—The cylinder barrel should be well oiled before putting in the piston. See that the lubricators on the cylinder connecting rod, and crank shaft bearings are filled with oil. The lubricator on the "cylinder" should drop five or ten drops of oil per minute on the piston, according to size of engine. Oil all other bearings about three or four times a day in the usual way, and see that none get warm from being too tight or too dry.

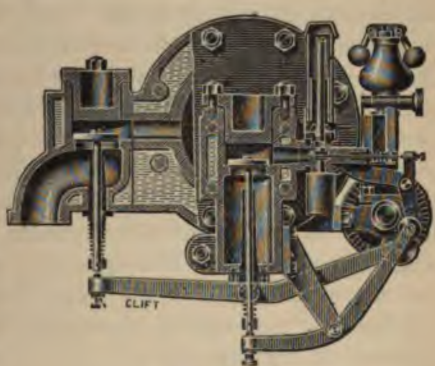


FIG. 179.

Starting the engine.—

1. Ignite the gas jet in the bottom of the chimney termed the "Bunsen flame," and allow the tube to be heated to a "bright red." This should not take longer than five to six minutes, providing it is a good Bunsen flame, and in the meantime all the parts of the engine requiring lubrication can be attended to preparatory to starting

2. Move the roller on the exhaust valve lever to the end of the stud so as to engage the second cam on the shaft. After the engine is started, the roller must be pushed back against the lever and secured there by the pin passing through the stud so that the lever can only be moved by one cam.

3. Open the valve on gas bag, get the gas bag full of gas, almost

close the valve, and turn the fly-wheel as quickly as possible. The engine should begin to run after the second or third revolution.

4. Open quickly, full, the valve on gas bag when engine commences to run.

Stopping the engine.—1. Never stop engine by shutting off gas at meter. Always shut the gas off at gas bag first.

2. Shut the valve on gas bag, and when the engine is stopped see that the letter O on side shaft is on the top; the engine must always be stopped in this way.

3. Shut the tap placed on the gas pipe to Bunsen burner, thus putting out the flame.

The governor.—The governor is so adjusted that immediately the engine over-runs its normal speed a "trip" or movable "peg" is pulled out of gear, and the mushroom valve (that admits the gas) ceases to move, and this cuts off the gas to the cylinder. This action goes on so long as the "trip" or "peg" is out of gear; but on the engine resuming its normal speed the "trip" is moved into gear with the mushroom valve by the action of the governor, and gas again enters the cylinder. The speed can be varied by adjusting the nuts under the spring that carries the weight. A special design of governor is used for electric lighting.

Note the following.—The piston must be taken out every three months, and the interior of the cylinder well cleaned, especially the combustion chamber. Scrape everything thoroughly out that may be left at the back, but if the oil and gas are good nothing will be found. At the same time remove all charred oil that may have collected in the exhaust ports and pipes.

The piston should not be taken out unless cleaning or new packing rings are needed. And it is also of primary importance that the piston should not leak; it is so constructed as to be capable of the most perfect adjustment. The rings should fill the grooves sideways as tightly as free movement permits. The "junk ring" is easily adjusted for the latter purpose. Be careful to see that the stops in piston ring grooves fit into the slots in the rings or the rings will get broken.

When cleaning piston it is strongly objectionable to do so by the use of emery cloth: the carbon should be taken off and then well saturated by either turpentine or paraffin, then wipe the piston body clean, and afterwards oil the piston and put it back in the cylinder. Never touch the piston with a file or emery cloth.

Piston packing rings.—Do not attempt to force these rings into the grooves over the piston. The junk ring must be removed, together with the division rings, and each ring placed in its own groove. Care should be taken to see that the figures on junk rings and piston packing rings are in a line with each other. The joints of these rings may require filing to suit the stop pieces that are in the piston, and these stop pieces must not be removed, but if necessary adjusted and altered to suit this pattern of ring; a mechanic will do this in a few minutes. Care should be taken to bed the new rings to suit the cylinder. To do this take out the piston after the engine has been working half an hour and file the bright places carefully with a smooth file. Repeat this operation until you see that the rings show bright all round. Great care should be exercised that the rings are thoroughly cleaned before putting back the piston, so that none of the filings or any dirt can get into the cylinder. We do not advise putting in new rings unless absolutely necessary, as the new rings cannot possibly fit the cylinder so well as the old ones, and very often the piston requires nothing more than the junk rings and the division rings "letting up" to prevent leakage between the sides of ring and the groove. The ring next to the explosion chamber will be the one first requiring changing.

Valves.—The exhaust gas and air mushroom valves on end of cylinder should be taken out and thoroughly cleaned every three months.

Difficulty in starting.—If the engine should stop or take longer to start without apparent reason, examine the exhaust gas and air mushroom valves on end of cylinder to ascertain whether any dirt prevents them from closing tightly; if so, grind them on their seats by turning them round by the shanks of the valves, it will then be felt that the valves are a perfect joint on their seats.

Bunsen flame.—See that the tube is equally heated all round. If "forks of flame" come up against the tube this causes a deposit of soot which prevents heating and is the main cause of tubes bursting. The Bunsen flame should burn equally and evenly and without any flame coming up sides of tubes.

Tubes.—If tube be not properly heated, engine "misses fire" and thumps and shakes foundation. Regulate the burner beneath this tube to give off a good Bunsen flame. See that the tube is heated to a bright red before starting the engine. At all times be careful not to have the "chimney" above the mark on the stud that

carries chimney. Varying gas pressure will affect the "Bunsen flame" and notice must be taken of this.

Freezing water in cylinder jacket.—If there be any danger of the water in the cylinder jacket freezing, during the winter months a small gas jet should be left burning underneath cylinder or the water must be drained off from the cylinder jacket. Provision is made for this.

Hard water.—When the water is hard a handful of common washing soda should be put in each tank every week.

Waste oil.—Drain the waste oil out of the bed; this can be done by unscrewing the plug out of the brass pipe; do not allow this plug to remain out. To prevent waste of oil in the lubricators on the pedestal caps, all the trimmings in the lubricators should be fastened with wire, and these should be removed out of the tubes in lubricators every time the engine is stopped. Also see that these trimmings are regulated not to allow any more oil to drop on the bearings than is necessary to keep them cool. Keep the lubricators well supplied with oil and clean all parts regularly.

Special.—Although a printed label is attached to the spur wheels directing mechanics in erecting the engine to gear the tooth in bevel wheel marked O with the space in pinion marked O, we again call attention to this point here, as mistakes are often made in putting these wheels together.

For the arrangement of pipes, sizes of same, and size of gas meter, also for foundation and all other necessary particulars for erecting, see foundation drawing sent with each engine.

"*Otto*" *Vertical Free Piston Engines* (Fig. 180).—Many of these are still in use, and are noisy but not complicated. There is no compression, consequently much less trouble with the piston and cylinder. In this engine the piston is driven up by the explosion to a height depending on the force developed, thus the stroke is variable; it does no work on this up stroke, but in descending pulls round the pinion by its rack by atmospheric pressure on the piston (see diagram Fig. 181), reaching about 10 lbs. vacuum by the time the piston begins to return; this and the weight of the piston and rack form the available power to turn the pinion shaft on the down stroke. These engines are fitted with slides and water jackets, and the governor regulates the frequency of the explosions. Fig. 180 is a section of one of these engines

The slide works vertically between the cylinder face and a back-plate, having springs with hand nuts to adjust the pressure, and it ignites the charge in a similar manner to the ordinary "Otto" slide by an internal port flame, re-lighted at every charge by a pilot jet in the back plate.

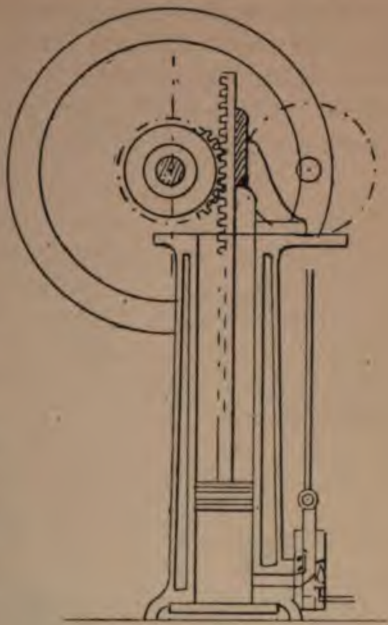


FIG. 180.

The clutch, which drives the shaft on the down stroke of the piston rack, has four loose wedge pawls with rollers which move freely one way but grip instantly when turned the other way.

The principal wear and tear falls on the clutch pawls, bearings, and the governor gear. The bearing brackets are too weak in construction and often get fractured.

The engine is excessively unwieldy for the power developed, a 1-H.P. engine weighing 18 cwt.

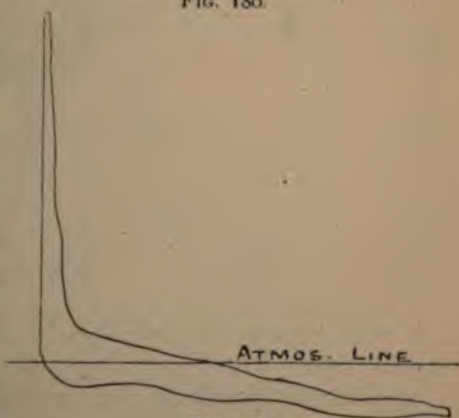


FIG. 181.

The Bisschop Engine is made by the same firm as the "Stockport," Messrs. J. E. H. Andrew & Co., Limited, Stockport. It is only used for small powers up to ½ H.P., and has a peculiar crank motion, which is shown in

Fig. 182. It is extremely simple, gas and air are admitted by plain spindle valves and exhausted by a port opened by a piston valve on the down stroke ; it takes an explosion at every up stroke when fully loaded ; there is no compression, and the consumption of gas is high. Fig. 183 is the diagram from this engine. It is very noisy, but where this and the cost of gas are not important it is serviceable from its simplicity ; no water

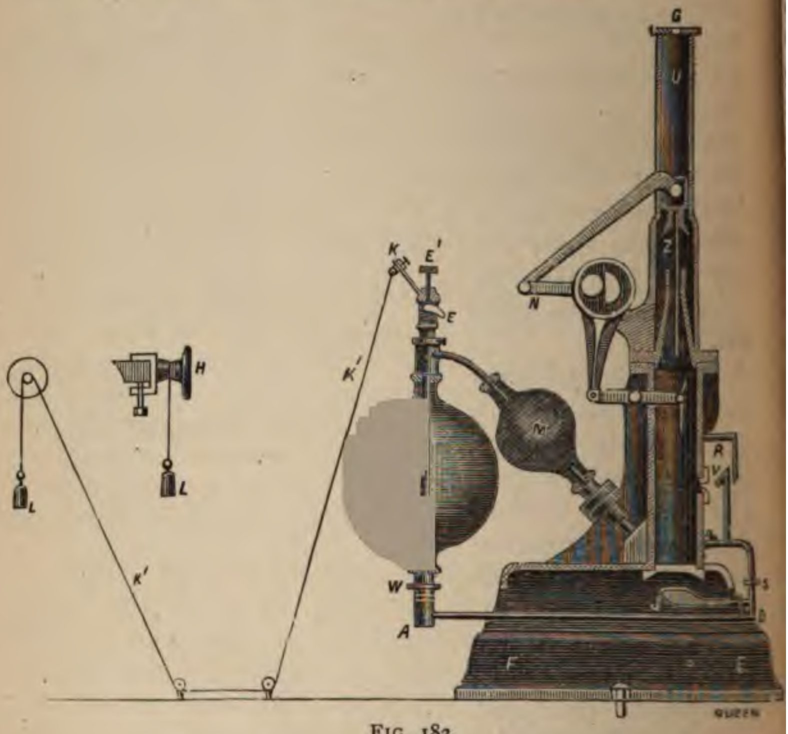


FIG. 182.

is used to cool the cylinder, but it is cast with a number of gills which carry off the heat into the air. Its piston gives less trouble than those of compression engines by leakage.

The engine is fed by gas through two rubber bags which act as reservoir and regulator. The gas admission valve is a thin iron disc with holes, covered by sheet rubber ; when the pressure in the cylinder is less than that of the gas, the

rubber sheet is lifted and gas passes into the cylinder. The air valve also opens towards the cylinder by suction and closes by the explosion. The ignition is by two gas jets, one of which lights the charge through a hole in the cylinder, and the other or "pilot" jet relights the igniting jet. The up stroke of the piston draws in air and gas to one-third its stroke, when the piston uncovers the ignition port, where the flame is sucked into the cylinder and fires the charge, which propels the piston the remaining two-thirds of the up stroke. On the down stroke the cylinder exhausts through the piston valve, which is operated by a lever and eccentric from the crank shaft.

FIG. 183.

The following instructions for working the Bisschop gas engine are supplied by the makers, Messrs. J. E. H. Andrew & Co., Limited, Stockport.

Foundation.—When placed on an upper floor, engine may be placed on a flag-stone about 3 inches thick, or other substantial foundation. The stone may be bedded on sheet felt. India-rubber may be placed between the engine feet and the stone, and all securely bolted to the floor.

Oiling.—The parts of the engine to be oiled occasionally are the slide box U, the crank shaft N, the crank pin, the eccentric and the rocking-lever These parts should be oiled with good oil before starting, and at intervals of every two or three hours. It is better to use a little oil at a time and often, than to pour oil on profusely. Parts should be wiped, especially the crank pin, after oiling, so that the oil is not thrown on india-rubber gas bags, which it will destroy. No oil of any kind must be put in cylinder or piston valve. To lubricate the piston valve it should be taken out *every morning and night*, before starting the engine, cleaned and greased lightly.

Starting engine.—After turning gas on at meter, open wide the cock W, and allow gas to enter large gas bag X. Then turn on and light igniting jet in chamber R. Turn on gas gradually by slowly screwing down the screw E′, on regulating tap at top of large gas

bag; at the same time with the left hand pull round the fly-wheel quickly until you get light explosions in the cylinder, after which screw down valve E, until engine runs at the speed and the power you require.

Stopping engine.—Always turn off gas at cock W, and squeeze all the gas out of large gas bag X. Then turn off gas at regulator E and lighting jets in chamber R.

Regulating engine by cord.—The speed of the engine may be regulated from any distance by attaching a cord K′, to the lever K, on gas regulating valve, the other end of the cord being wound round the pulley on bracket H, sent with engine. This bracket H may be screwed to any convenient place. By turning the handle on bracket H in one direction or the other, the gas supply can be regulated to the engine so that it runs faster or slower as required. The cord may be carried by pulleys along the floor or ceiling, the lever K being adjustable.

Speed of engine.

Speed of	1-man	engine should not exceed		140	revs. per min.
"	1½	"	"	130	"
"	2	"	"	120	"
"	4	"	"	90	"

The above speeds can be reduced considerably when the engine is doing light work.

Do not let engine stand for any length of time without working. If not convenient to work engine a short time every day, the fly-wheel should be moved round by hand occasionally.

Causes of irregularity in the "Bisschop" Gas Engine. Fly-wheel and pulley loose.—If a fly-wheel or driving pulley is loose, or if there is any play endways between the crank and the fly-wheel, the engine will make an excessive noise.

Igniting valve sticking.—The igniting valve may stick fast; a gentle probe with a match will loosen it.

Light being blown out.—The joint of igniting valve against cylinder may be bad and require a new asbestos joint ring.

Igniting valve out of order.—The igniting valve itself may be out of order and require renewing. On no account must the igniting flame be left burning when the engine is stopped, or it will destroy the igniting valve.

Igniting flame.—The burner which ignites the charge may be

ked with dirt, and so reduce the length of flame (this flame should be less than 5 inches long). The bottom flame ought not to ch the top flame.

India-rubber valves for air and gas inlet.—See that the india-ber valves for admission of air are in good condition. The htest crack or hole or hardness in the india-rubber will reduce power of the engine. If the india-rubber is greasy it has the me effect.

If the screws are screwed too tightly it will so compress the bber that sufficient air cannot pass. Great care should be taken t to screw up the set screws too tightly. See that lift plate is not versed in air valve.

The india-rubber of gas valve should be very carefully examined. his valve is subjected to a greater strain than the air valve and is ore liable to get greasy, therefore examine this valve very carefully see that it is in perfect condition, and that the plate which keeps e india-rubber to its face is the right way up. This plate should t touch the india-rubber at the tongue. If it does touch, the valve ll not open sufficiently to admit the proper quantity of gas.

After examining the air and gas valves be very careful to make od the joints with the asbestos rings, as any escape, however ght, will materially reduce the power of the engine. In replacing vers screw up evenly on both sides.

It is of the highest importance that the proper quality and ckness of india-rubber should be used. It is therefore advisable obtain these valves from the makers of the engines.

Air, gas or exhaust passages blocked.—See that there is a ar passage for both air and gas, as sometimes these passages are choked with dirt and corroded grease that the proper charge ore particularly the gas passage) cannot pass into the cylinder. ape thoroughly all these passages, and ascertain if the exhaust sage is perfectly clear. If the gas passage is blocked it can be ected by the small gas bag being unduly inflated.

Eccentric loose.—If the eccentric is loose and has shifted on the ft the engine will not work properly. There is a hole in the nk shaft to receive the point of the set screw in eccentric. ticularly notice if the set screw is in that hole, and that it is ewed up tight.

Cleaning cylinder.—If oil has got into the cylinder it will set d on the sides, make it very rough to the touch, and the engine

will run very heavily when turned by hand. When this happens the cylinder should be thoroughly well scoured with emery cloth until all the rough places disappear to the touch, and take this opportunity of thoroughly cleaning all the passages to and from the cylinder, viz. air, gas and exhaust passages.

Taking engine to pieces.—When taking engine to pieces be very careful not to strain the piston rod when lifting off the slide-box. A little extra help at this stage (lifting off the slide box) may save months of annoyance, as, if the piston rod is strained, the engine will not work satisfactorily. Before taking off slide box, the cross-head must be taken off piston rod.

When taking out and cleaning the piston deal very gently with the piston rings, as they are very brittle, and do not take them off the piston unless absolutely necessary. If the rings are fast they require renewing.

The above remarks apply equally forcibly when putting the engine together.

If the piston rod has got strained it should be put in a lathe. It is better to put cross-head on piston rod before putting in lathe, and try all together, and great care taken to make the piston run perfectly true while between the centres of the lathe.

When the piston is in the cylinder, and the slide box is in position, it can be readily ascertained if the piston rod is true by raising it a little from the bottom of the cylinder and lowering the cross-head on to the end of the rod, and noticing if the hole in cross-head and end of piston rod come exactly together without springing the piston rod. Unless the piston rod does so couple, the engine will not work satisfactorily.

In putting slide box on to cylinder no joint ring is required, but it should be seen that both faces are clean and free from dirt before putting together. See that the marks on the slide box and cylinder flanges are exactly opposite each other.

Rusting of slide valve.—The rusting of the slide valve may be caused by the water formed in the exhaust pipe not being able to get away, as, if the exhaust runs upwards from the engine, all the water formed in the exhaust pipe flows back to the cylinder when the engine is not at work. To prevent this an outlet must be made in the lowest part of the exhaust pipe.

The exhaust pipe may be so choked with dirt and corrosion as to cause back pressure to the engine.

General Remarks.—If bad oil is used, engine will run very stiffly, l a large amount of power will be absorbed in friction. When gine is stiff from this source put a little paraffin oil on the bearings d slides so as to scour them, but discretion should be used in its e as it is not a lubricant.

A low pressure of gas or an insufficient supply will cause regularities. This insufficiency of gas may be caused by having o small pipes, or the pipes may be choked at some particular oint by dirt or corrosion, having too small a meter, or the meter eing out of order, or water accumulating between meter and engine.

If the pressure of gas is very low, it is advisable to have a gas ressure raising apparatus, which we supply, particulars of which may e had on application.

If the engine is turned backwards quickly by hand as the piston s descending, it ought to rebound, and will do so if all the joints are ood and engine is in good order, and not stiff in bearings.

In no case must steel or brass rings be put in piston.

Atkinson's Differential Gas Engine is one of the most conomical manufactured. It is of the four-cycle type, but y a curious and ingenious crank motion, the piston makes ur strokes to one revolution of the crank. The charge is xpanded down to twice its original volume and thus to a ower pressure than usual before exhausting, thus getting nore work out of it and making the exhaust quieter than ith the Otto and Stockport types. There is no slide, and ube ignition is used; the valves are all three of the spindle orm, gas valve, air or suction valve and exhaust valve.

The Griffin Engine is a high speed engine, made both ertical and horizontal. It has a closed cylinder, works on e three-cycle plan, clearing the cylinder entirely after each pulse, and with slide ignition. The charge of gas and air fired on each side of the piston alternately, once every three volutions, giving one impulse to each turn-and-a-half of the ank. The vertical engines are single acting, and the horintal ones double acting, the latter having separate sets of ves, slides and gear for charging and exhausting at both ds of the cylinder; these are operated, as usual, by a side aft driven by helical gear from the crank shaft, and of

course require two pilot lights and two sets of lubricating tubes for the slides. Fig. 184 is a side view of this engine, double acting. The slides work vertically, and are driven by

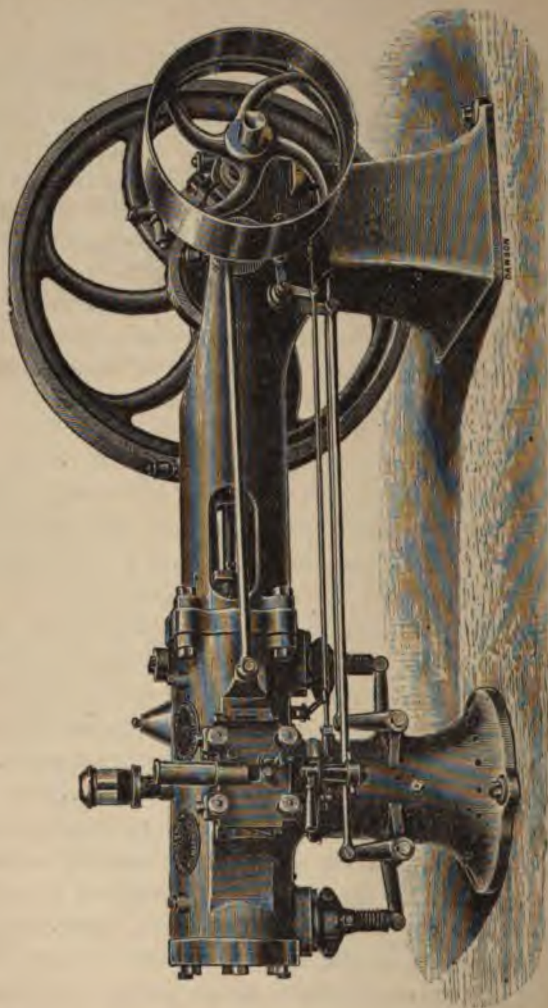


FIG. 184.

eccentrics. The exhaust valves are opened by cams and levers, and reseated by springs as usual. The general design is neat and effective.

The governor has a small double-ball, with a conical ight on it, and is driven by gear from the side shaft, enclosed an oil box.

The action of this engine is as follows:—On the out stroke piston moves forward, drawing in gas and air, which are npressed on the return stroke; the mixture is then fired and ves the piston forward. On the next return stroke the es are expelled. During the next out stroke a scavenging rge of air only is drawn in, and exhausted on the return oke. The same cycle of operations takes place at both ends the cylinder.

The horizontal engine has an impulse at each one-and-a-f revolutions when fully loaded, and therefore is more werful for its size, and more steady than any other type, th the nearest approach to continuous impulse. The later gines have tube ignition.

The latest form of this engine is a duplication of the)tto" cycle, giving one impulse to two revolutions by plicating the valve gear at each end of the cylinder. Large wers can thus be obtained without double cylinders and nks.

Day's Patent Gas Engine, shown in section in Fig. 185, is o one having an impulse at every revolution, and possesses ne special features. The cylinder is vertical, and the nk and connecting rod enclosed in an air-tight box below. has no slide valve, and, in fact, only one valve; the ton and ports in the cylinder effect the distribution of air l gas.

One lubricator on the side of the cylinder supplies oil to the working parts enclosed in the box; there is no escape gases from the cylinder, and the engine will run in either ection. The ignition is by a hot tube, with Bunsen burner the ordinary form.

A water jacket, circulating pipes and water vessel are used, in other engines, to cool the cylinder. The crank box is pt partly full of oil in which the gear runs, and this oil ıst be renewed occasionally, as the waste oil from the

cylinder also runs into it; there are taps for both filling and emptying the chamber. The lubricator has a screw valve for regulating the flow of oil. In starting, the fly-wheel must be pulled round sharply, at the same time turning on the gas, and the speed must be regulated by the governor adjustment. It works on the two-cycle plan, taking gas at each revolution when fully loaded.

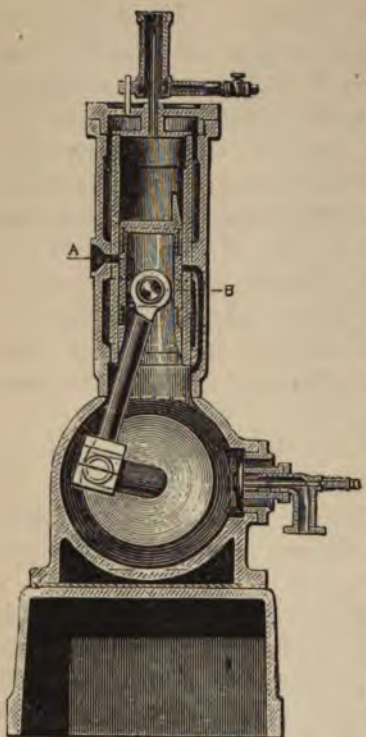


FIG. 185.

The engine contains but one valve, and this, shown at Fig. 185, is self-acting. The crank works in an enclosed chamber, and is connected to the piston, which is of the trunk type, by a connecting rod in the usual manner. On the side of the crank chamber is an automatic reflex-acting beat valve. This valve is for the purpose of admitting in controlled proportions air and gas. On the up stroke of the piston a partial vacuum is formed in the crank chamber, and a charge of air and gas passes into it through this valve. On the descent of the piston the mixture is compressed slightly—in practice from $1\frac{1}{2}$ to 2 lbs.—and under this pressure the mixed charge rushes into the working part of the cylinder through the ports shown, and as follows:—A port B, Fig. 185, connecting the crank chamber with the working part of the cylinder, which exhausts at the bottom of the stroke, is covered by the piston. Just before the piston completes its downward stroke this port B is uncovered by it, and the mixture in the crank chamber is free to rush up into the space above the

on. The piston returns, the mixture is trapped, compsed, and fired in the ignition tube in the ordinary way. piston then comes down under the explosion, and just re the inlet port is reached it uncovers another port A ning to the exhaust pipe. Not till this is fully open is the t port B uncovered and the incoming charge admitted. e in-rush of the explosive charge is used to effect the arance of the waste product. On its entrance it impinges inst a deflector fin on the end of the piston, which, by flecting the incoming charge, establishes an eddying action the cylinder. The piston rises, closes both ports, and the ocesses of compression and ignition are repeated. Thus an pulse is obtained at every revolution.

It will be seen that it matters not in which direction the gine runs. The governor actuates a circular grid covering e air passage, and by thus varying the freedom of admission the air, regulates the speed of the engine.

The following instructions are issued by the makers.

1. See that Bunsen burner is properly lighted and that ignition e is a *bright* red heat.

2. See that lubricator is filled with proper gas engine oil, and that screw valve is so adjusted as not to admit of oil running out too t.

3. Whilst turning on gas, give the fly-wheel a sharp turn or two the direction in which the engine is to run.

4. The engine should start at once, but the governor will have to regulated according to circumstances, quality and pressure of gas, l so forth.

5. The speed is from 160 to 250 revolutions per minute, accord- to size of engine.

6. The quality of oil used is most important.

7. *The condensed products of explosion produce water.*—Guard inst the accumulation of this in exhaust pipes and exhaust box, which a plug is provided for emptying exhaust box.

8. A tap is provided for filling oil into crank chamber and for ptying same. When lever of tap is in line with tap the waste oil 1 be drawn from crank chamber, and this should be done periodi- ly. When lever is at right angles oil can be poured into crank

chamber, and when turned in the opposite direction it is shut off, and this is the position in which it should be when engine is at work.

9. All water pipes should slope upwards towards the circulating tank.

10. Provision should be made, when connecting engine to tank, for emptying water jacket of engine in case of frost.

11. The exhaust box should not be fixed above the level of the engine.

The Premier Gas Engine is a small power engine with some special features. Its water tank is contained in its base. It works on the Otto cycle with compression, and simply requires gas and exhaust pipes connected up to start

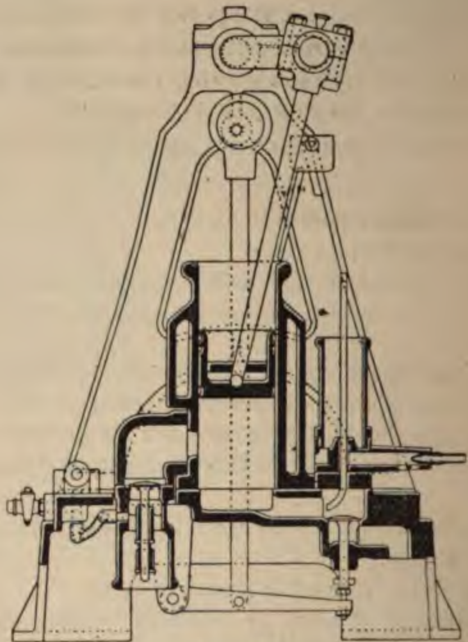


FIG. 186.

it anywhere. The ignition is by hot tube, and the valve gear driven from the crank pin by a rod working a rock-shaft at the back of, and below the cylinder.

The Roots Economic Gas Engine is shown in section in Fig. 186, in the vertical form, and in elevation in the horizontal form in Fig. 187. It is made of both the horizontal and vertical

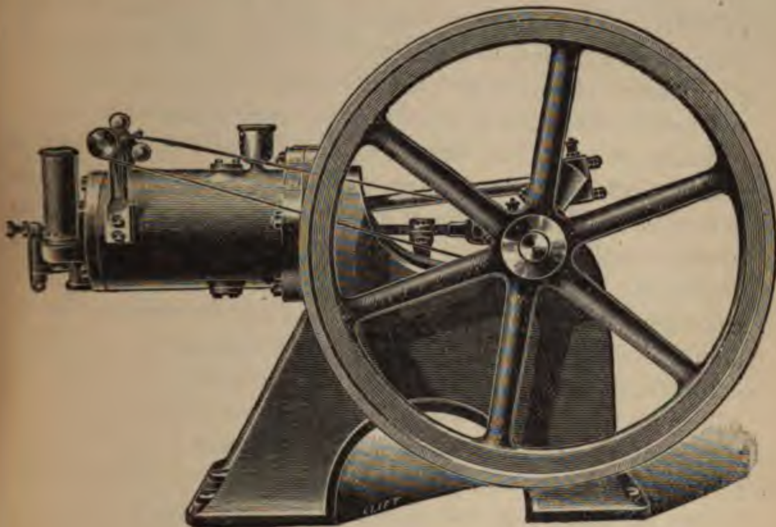


FIG. 187.

forms up to 6 H.P. The air and gas valves are on the left side in the section, and the exhaust valve and tube igniter on the right. It has the "Otto" cycle, but with a double explosion impulse, the charge of air and gas being compressed partly into the chamber above the air valve and partly below the piston; the latter is ignited first, and fires the chamber charge when the piston passes the port; this second impulse is given with the crank at about half stroke, and is therefore more effective than when on the dead centre. See also the Roots Oil Engine, Chapter X.

The engine works on the Otto cycle, in so far that there is but one impulse for two revolutions of the crank shaft, but the compression of the charge is effected in a novel manner. The admission valve, which is shown to the left of the diagram, opens into a compression chamber and not directly into the cylinder. During the suction stroke of the engine the air and

gas are drawn through the suction valve, which, we may add, opens automatically, and expels the burnt products from the compression chamber, leaving in this chamber a very rich mixture, whilst a poor mixture only is found in the working cylinder. On the return stroke, before the compression has proceeded very far, the piston closes the port between the compression chamber and the cylinder, and during the final portion of its stroke only further compresses the small quantity of poor gas, consisting largely of the products of combustion from the previous working stroke. This mixture is fired at the end of the stroke by the tube igniter. The pressure rapidly rises and the piston commences its working stroke, and soon uncovers the port leading to the compression chamber; the rich charge here is then rapidly compressed to about 120 lbs. per square inch by being thus put in communication with the burning gas in the cylinder, and fired, the effects on the diagram being clearly shown. Thus, after the first explosion the pressure begins to fall, and when the port to the compression chamber containing gas at a low pressure begins to open, this fall is accentuated, but very soon the fresh charge in the chamber is fired, and the pressure line rises again, and is well maintained for a considerable proportion of the stroke. At the end of the working stroke the exhaust valve is opened by the action of an eccentric worm.

The makers claim that their experiments show a considerable economy of working by the peculiar system of compression adopted. It is known that the higher the compression in a gas engine, the higher the economy, but in practice it has not hitherto been found possible to adopt in ordinary work a greater compression than 60 to 65 lbs. per square inch.

The Allison Engine is of the Otto type, four-cycle plan, cylinder horizontal, tube ignition; the air and exhaust valves are operated by cams and levers from the usual side shaft, which is driven by screw gear from the crank shaft. The governor is of the pendulum form, swung from a side pin on a vertical lever oscillated by a cam. It has a water jacketed cylinder, with

open ram, and the connecting rod is jointed to the base of the ram as in the "Otto" and many others. The general description of the gas engine in detail on pp. 136–148 applies also to this engine.

The "Trusty" Engine is also a four-cycle engine of similar design to the "Allison," with tube ignition, side shaft, air and exhaust valves worked by cams and levers from the side shaft; gas governor of pendulum form. See the Trusty oil engine, p. 191.

The Robey Gas Engine.—This engine is manufactured under the Richardson and Norris Patents. It is worked on the four-cycle principle, i. e. an impulse is obtained at every other revolution.

The regulation of speed is effected by the Richardson governor, similar to that used on all classes of Robey engines.

The ignition in small engines, say up to 7 horse-power, is effected by the well-known tube ignition. These tubes are ¼-inch bore, and made from the best drawn tube metal, the average life of the tubes being about 120 hours. In large engines tube ignition is used in conjunction with a mechanical igniting arrangement, which also serves for delaying the time of ignition when starting by hand.

One small but by no means unimportant detail, to which great attention has been paid, is that of the cylinder lubricator. This is on a principle which has long been in use in marine and stationary engines, viz. a revolving carrier alternately dipping into an oil well, and depositing a drop of oil upon a tube, from which it descends to the bearing. The peculiarity of this lubricator is that the operation is performed in duplicate; one carrier simply serving to keep full to overflowing a second reservoir, from which the oil is finally conveyed to the cylinder. By this means the level of the oil in the cistern from which the oil is taken by the dipper to drop into the cylinder is kept constant, an absolutely uniform flow of oil is insured throughout the day, irrespective of the amount of oil in the main oil cistern.

Another important feature in the engine is the ease with which it can be made to run in either direction. By an

arrangement of the eccentric lever this can be done in two or three minutes. The cylinder and bed-plate are in one casting, and inasmuch as the cylinder and crank-shaft bearings are bored at the same time by specially designed tools, there can be no question of their being accurately at right angles. The joint between the combustion chamber at the rear end of the cylinder itself is a metallic joint, the two parts being ground together exactly in the same way as in a circular-seated steam valve. The whole of the valves controlling the admission of gas and air are vertical, and therefore not liable to wear oval in form. The bearings of the crank-shaft are ample. All parts subjected to heat are water-jacketed, including the cylinder and the parts containing the valves and valve springs.

The "Fielding" Engine is manufactured of both vertical and horizontal types. It has the "Otto" four-cycle principle with hot tube ignition regulated by a timing valve. The admission and exhaust valves are worked on one spindle from an eccentric on an intermediate shaft driven by 2—1 gear from the crank-shaft. The governing is effected by a rotary governor, which raises or lowers a lever carrying a hit-or-miss blade. In the ordinary way, therefore, gas would be admitted when the engine is moved at low speed, but the ignition of the charge can only occur when the crank is just over the centre, as the time of ignition is controlled by a lever, which is worked by a roller on the main valve crosshead block. In order to obtain half compression, the piece on the rod is made so that when turned by hand one quarter revolution, it comes into contact with a piece on the exhaust-valve rod, and thus holds it open during part of the compression stroke. The engine is usually fitted with a self-starter for the larger sizes.

The "Express" Engine manufactured by Messrs. Furnival & Co., Reddish, is also of the "Otto" four-cycle type. The gas, air and exhaust valves are all of the conical spindle form and operated by levers from cams on a side shaft. The gas valve is only opened for a time during the middle part of the suction stroke, so that the middle part of the charge is richest in gas. The engine has tube ignition and a timing valve.

The charge is fired in the centre instead of at the front end as in many other engines, as it is richest in gas at the centre. The connecting rod has a neat arrangement for taking up the wear at the piston end by a long screw, so that it is not necessary to take out the rod.

The Campbell Gas Engine (Fig. 188) is of the overhead cylinder type. The engine has two valves, one for the admission of gas and air; this is automatic, and opens when the piston

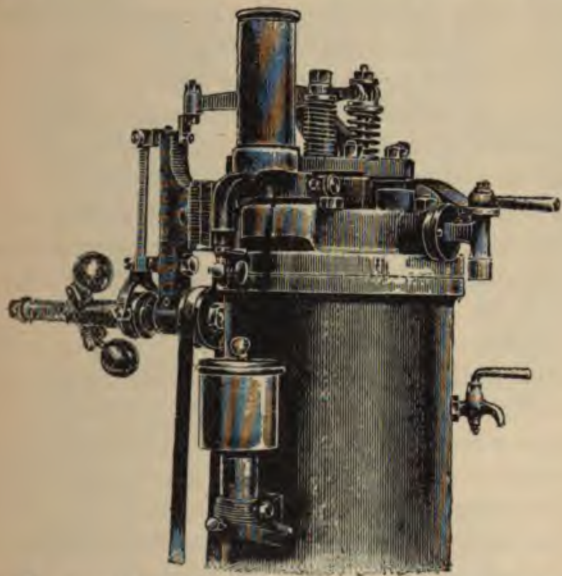


FIG. 188.—CAMPBELL VERTICAL GAS ENGINE, SHOWING UPPER PART OF CYLINDER AND VALVE GEAR.

moves downwards; a light spring on the end of the spindle closes it when compression commences on the up stroke. Ignition on crossing the dead centre takes place by a heated tube. The other valve is the exhaust valve, and it is opened on the upstroke of the piston by an eccentric rod and pusher, which acts upon the end of an adjusting screw on a lever attached to the exhaust valve spindle. The governing is done by an ordinary centrifugal governor, driven by a small belt from the crank shaft. The governor prevents the charge of gas and air

being drawn into the cylinder by holding the exhaust valve open, so that the partial vacuum necessary to open the gas and air valve is not created by the piston, and as the inlet valve depends on the vacuum to open it, it remains closed, when the vacuum is destroyed. For the inverted cylinder engine, as compared with the overhead crank type of gas engines, several advantages are claimed; namely, that the bearings are always in constant thrust, and the force of the explosion is transmitted directly to the foundations instead of the caps of the crank bearings. The power is taken from the engine below instead of above the centre of gravity, which is, moreover, lower than the crank overhead type. The stresses in the engine frame are lessened, and vibration caused by the pull of the belt several feet above the floor obviated. The engine is very well arranged.

The Purnell Gas Engine.—This is an engine for small powers (up to 2 H.P.) of the vertical overhead crank construction (Fig. 189). The mixture of gas and air is admitted at the up-stroke of the piston by a self-acting valve into a space at the bottom of cylinder. The piston on its down-stroke compresses the gaseous mixture, a portion of the charge being forced into a red-hot ignition tube, where it is ignited. The ignition is communicated to the charge in the cylinder and the piston is propelled upwards. As the piston descends, it causes an exhaust valve to be opened, and the products of combustion are thereby expelled. It will be seen that this engine is greatly simplified by the admission valve being self-acting, and by its having no ignition valve. The engine is controlled by a governor, which can be set to allow the engine to run from 60 to 250 revolutions per minute. This is accomplished by simply altering the compression of spring on the vertical governor spindle. By allowing the spring to be nearly at its full length, the gas is cut off sharper and the engine runs slower. By compressing spring almost to its smallest compass, the governors are loaded and the engine runs at its maximum speed.

The Dudbridge Gas Engine has the "Otto" or four-cycle, and is manufactured both vertical and horizontal with tube

gnition. There is no timing valve, the point of ignition being regulated by adjusting the height of the burner. The valves

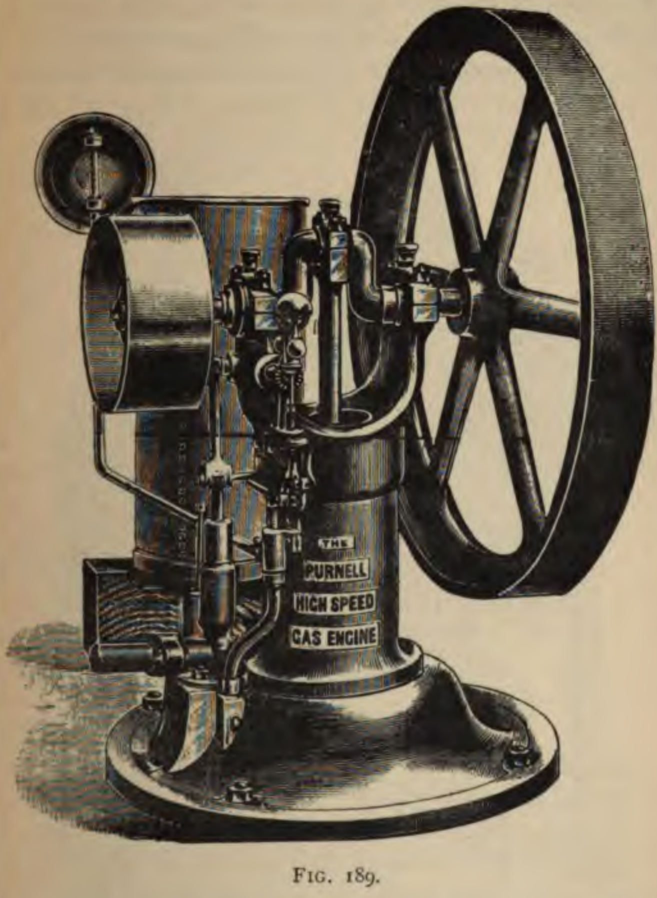


FIG. 189.

e each in a separate valve box for easy access, and are iven by cams on a side shaft, which is driven by helical gear the usual kind. The larger engines are fitted with a starting ar.

The "Castle" Gas Engine is nearly identical in description th the Dudbridge.

The Forward Gas Engine (Fig. 190) also has the "Otto"

cycle in the later patterns, with tube ignition fitted with incombustible tubes, adjustable governor, no timing valve, and the engines are fitted with the Lanchester self-starter (see p. 201).

The makers consider a timing valve quite unnecessary. The pistons have four cast-iron rings, each ring having a check groove turned in its circumference; this grooving is calculated to prevent, more or less, the leakage of the hot

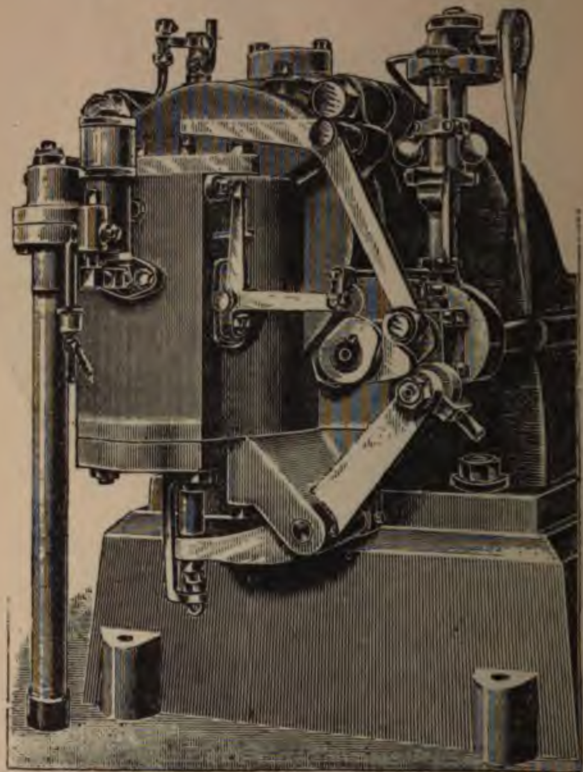


FIG. 190.—VALVE GEAR AND GOVERNOR, FORWARD GAS ENGINE.

gases past the rings. Fig. 190 is a view of the valve gear and governor at back of the cylinder.

The National Gas Engine is also of the "Otto" cycle with tube ignition fitted with patent permanent tubes and timing

valves, also self-starters to the larger sizes. It has a rotary admission valve, with adjustable cover lined with anti-friction metal, so as to reduce the wear of the valve to the minimum. This valve has been since replaced by independent spindle valves with lever and cam movements from a side shaft as in the "Otto," and others described in the foregoing pages.

CHAPTER X.

OIL ENGINES.

GAS engines are also constructed to consume oil, thus becoming oil engines, by fitting them with an oil tank, an oil pump and a vaporiser, in addition to the usual gas details; also an arrangement by which the governor regulates the admission of oil to the vaporiser. The methods of vaporising the oil vary.

The kinds of oil used comprise any and all of the cheap kinds of petroleum or paraffin, which are vaporised by heat at temperatures above 150° F., but in some cases a separate gas-making apparatus is used, in which fats and oils of every kind of mineral, vegetable or animal origin, can be vaporised and used in a gas engine; such a plant consists of a furnace, retort, purifier and gasometer.

The peculiar troubles incident to oil engines arise from the oil fuel which may choke the ports or exhaust by burnt deposit or soot. The cylinder and piston may also get fouled from the same causes. Faults in the oil feed, either from over supply or deficiency, will interfere with continued working or cause stoppage. The oil heating jets also are liable to cause trouble by smoking or flickering from draughts of air.

The Priestman Oil Engine (Fig. 191) uses from 1·25 to 1·6 pints of oil per actual H.P. per hour. The oil is contained in a tank inside the bed plate.

It is designed for the use of heavy hydro-carbon oils, which are treated in such a manner as to avoid the secretion of

tarry products on the walls of the cylinder and internal working details, and thus obtain perfect combustion.

By means of a small charge of compressed air, the oil is broken up into what may be termed a very fine "oil dust," and is drawn through a heated chamber which is warmed before starting with a small lamp, and is afterwards kept hot by the exhaust gases. In this chamber the temperature of the vapour is raised, and being mixed with a large amount of atmospheric air, is drawn into the cylinder and ignited by means of an electric spark.

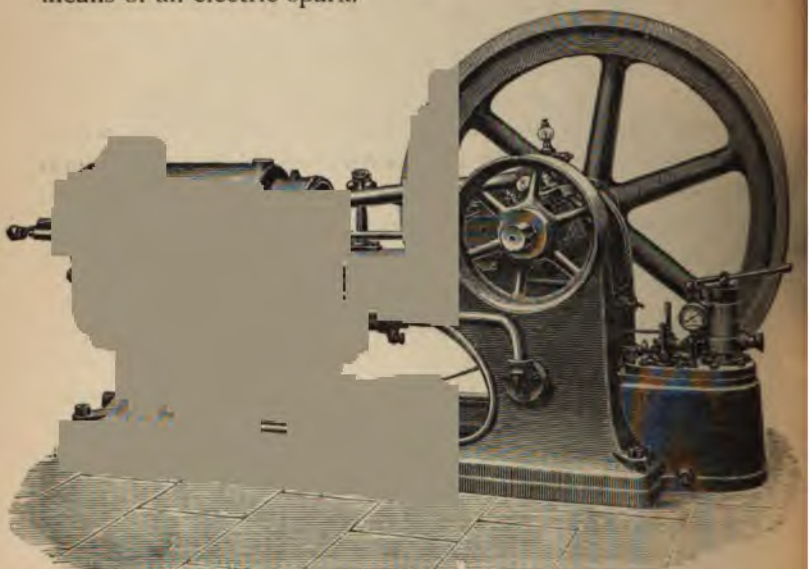


FIG. 191.

With the use of the latest form of igniter, the engine can be worked for three, six and twelve months or more, without so much as touching the elements from which the spark is obtained.

Electric ignition is undoubtedly the most certain and the most ready of the methods in use. It enables the engine to be started immediately, without preparation, and gives no trouble from burning out. The carbon electrodes are easily attended to. It is curious to note that the first gas engines

were fired in this way, although the difficulties with the electric apparatus were very much greater than now.

The makers claim that the oil in this engine is perfectly consumed, leaving no deposit of tarry matter on the cylinder or exhaust pipes, and this seems to be borne out by numerous actual tests. This is effected by the system of breaking up the oil into a mist or fine spray, so that it is thoroughly mingled with the air. The following is from the *Engineer* :—

Fig. 191 is a perspective view of the engine; Fig. 192 a section of the cylinder; Figs. 193 and 194 are section and end views of the spray

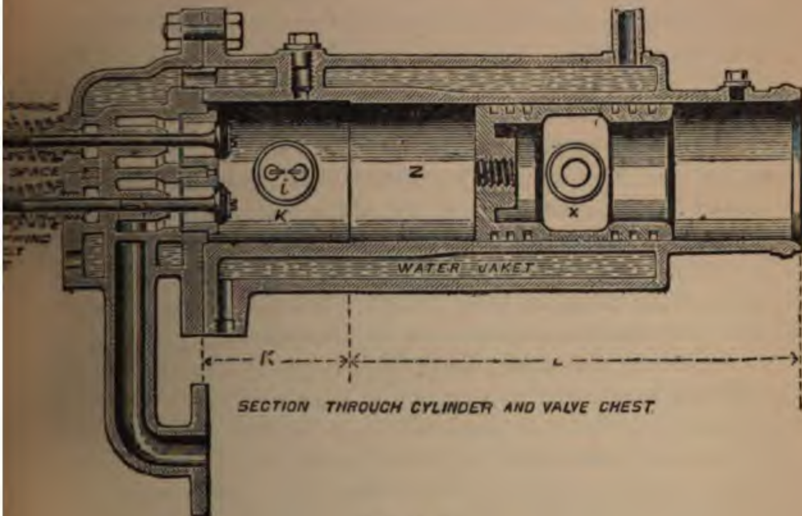


FIG. 192.

maker. Z is the working cylinder; X is the piston; K the clearance space into which the air and vapour are compressed before explosion. The supply tank for oil is below the cylinder. To deliver the oil from this tank to the spray-maker S, Figs. 193, 194, or starting lamp below the vaporiser, an air pressure is maintained in the tank, which is produced initially by a small hand pump, and afterwards maintained by a pump, driven by the eccentric. A spring loaded escape valve on the oil tank keeps the air pressure constant. This pressure can be regulated, and is shown by a gauge on the tank. There is also a glass gauge showing the oil level in the tank. O is

the vaporising chamber, provided with a jacket through which the hot exhaust passes. Below this is the lamp used in heating the vaporiser initially, and this is supplied with oil and air from the oil tank. On the oil tank is a six-way cock, arranged very simply. When the handle is upright, the cock is closed; when turned to the left, air and oil are supplied to the starting lamp; when turned to the right, air and oil are supplied to the spray-maker S. The engine cylinder is water-jacketed, the water being circulated either by gravitation from a tank or by a special pump on the engine. At the back of the cylinder are two valves, one being automatic and the other opened by an eccentric. The upper or automatic valve *s* opens on the suction stroke, admitting the mixed air and vapour from the vaporiser. The lower valve *e* is opened during the exhaust stroke, by an eccentric on a shaft rotating at half the speed of the crank shaft. Through this valve the exhaust gases pass to the jacket of the vaporiser, and thence away. At the back of the engine, not shown, is a bichromate battery and induction coil used for igniting the charge. The circuit is completed at the proper moment by a contact finger on the eccentric rod, which passes between a pair of springs, and then closes the circuit except for the break between the two electrodes. A screw plug *i*, Fig. 192, in the side of the cylinder, contains two porcelain bars, through which the electric wires pass. The electrodes in the cylinder are platinum wires.

In starting the engine, the oil tank is put under pressure by the hand pump, and the lamp under the vaporiser lighted. When the vaporiser is hot enough, which will be in between eight and twenty-five minutes, according to the size of the engine, the six-way cock is open to admit oil and air to the vaporiser. The fly-wheel is then turned, the engine draws in an explosive mixture, compresses it and starts. The cycle of the engine is the ordinary Otto cycle—that is, the explosive mixture is drawn in during a suction stroke and compressed in the return stroke. At the moment of full compression the charge is ignited, and the working stroke is effected by expansion. The next return stroke drives the products of combustion through the exhaust valve.

It is rather an important practical incident in the working of the engine that, during the compression stroke, a small portion of oil condenses on the cylinder surface and lubricates it perfectly. The cylinder requires no other lubrication.

The most important organ in the engine, and the one on which

ts satisfactory action mainly depends, is the spray-maker, Figs. 93 and 194, and, in connection with this, it is necessary to onsider the arrangements for controlling the air and oil supply by he governor. The actual spray-maker consists merely of two small oncentric nozzles E, the inner one discharging a jet of oil, and the

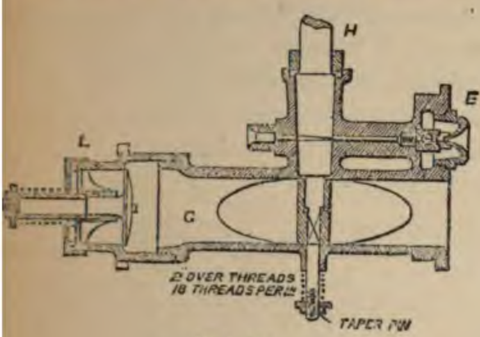


FIG. 193.

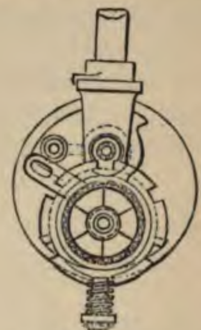


FIG. 194.

uter a jet of air, both forced out by the air pressure in the oil tank. he form of these nozzles is such that the fine oil jet is torn up into mist of fine particles and driven forward into the vaporiser. Then ne oil is heated and vaporised till the suction stroke begins. Then much larger additional supply of air, coming through the non-eturn valve L, passes the throttle valve G, enters the vaporiser nrough small holes at the end of the vaporising chamber, and sweeps ne heated charge into the cylinder, the end E of the spray-maker, ig. 193, entering and being fixed to the vaporiser. The form of he spraying nozzles was only arrived at after numerous trials. tecently Messrs. Priestman have brought out a self-starter for their il engines.

Crossley's Oil Engine has a vaporiser at the back end of he cylinder which is heated by an oil burner, which also eats the ignition tube; this burner is fed by air supplied y a pump. The oil is pumped into the vaporiser by a mall pump, controlled by a governor, and the oil vapour lrawn into the cylinder in the same way as gas, the nixture being compressed and exploded, as in their gas ngine. In all other details, the engine is similar to their vell known "Otto" type, as described in detail on pp. 149–155.

The Hornsby-Akroyd Patent Safety Oil Engine.—This engine is horizontal and in appearance and design is somewhat similar to a gas engine, the now well known four-cycle plan of operation being used, as in the best modern gas engines.

The engine is constructed (as Fig. 195), with a working cylinder, closed at one end by a cover and open at the other. In this cylinder the piston works, which is formed like a plunger, being open at one end to receive the end of the connecting rod. The connecting rod is attached at its other end

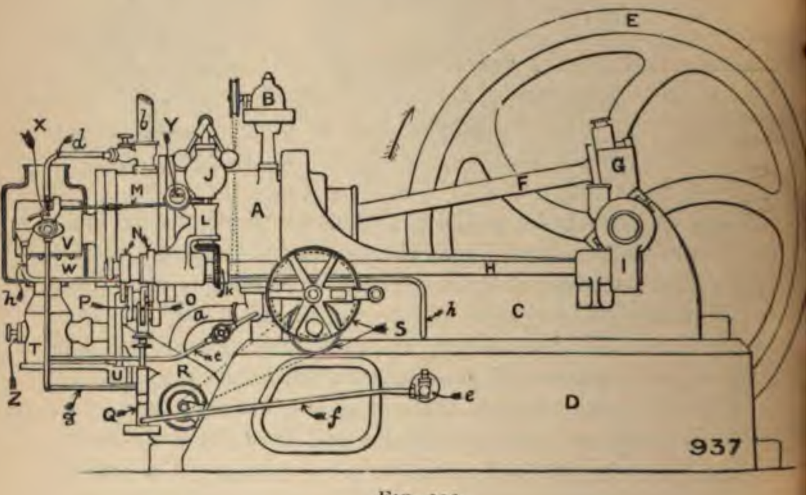


FIG. 195.

to the crank. Near the closed end of the cylinder a valve box is fitted which contains two valves, one being the air valve and the other the exhaust valve. The air and exhaust valves are opened by separate levers, each lever being moved by a cam mounted on a horizontal shaft, driven by the crank shaft through skew or bevel wheels. This horizontal shaft makes only one revolution while the crank shaft makes two, so that the air and exhaust valves are each only opened once every two revolutions.

At the back of the cylinder is a cast-iron box V called the vaporiser, which is always opened to the cylinder A through a

eck. This vaporiser is heated before starting the engine by n external lamp T, blown by a small hand fan R for a few ninutes : this is done so that the vaporiser shall be able to raporise and explode the oil when it is pumped into it. After the engine has started running the lamp is no longer required, the vaporiser being kept at a sufficient heat by the explosions which take place in it.

A small oil pump Q, worked by the air valve lever, draws oil from the oil tank under the engine, and forces it into the

FIG. 196.—PART SECTION OF CYLINDER AND VAPORISER.

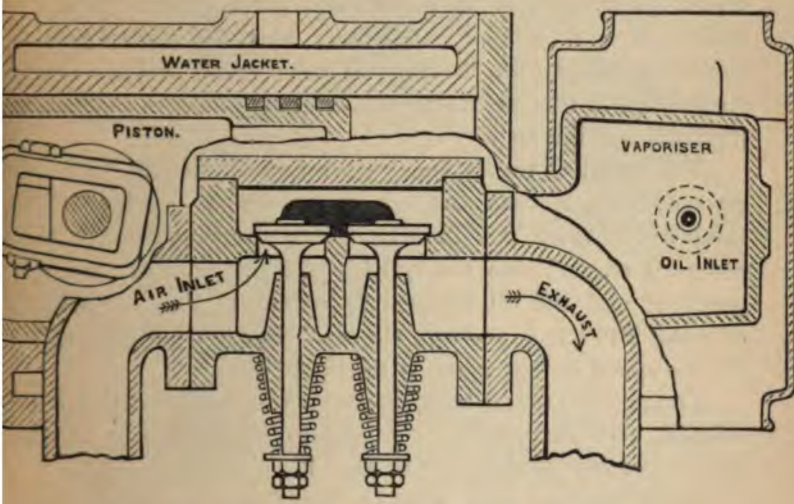


FIG. 197.—SECTION THROUGH VALVE BOX.

vaporiser ; this takes place only during the out-stroke of the piston, when it is drawing in air. The oil on its way from the pump to the vaporiser passes through a valve box X attached to the vaporiser ; this valve box has two valves in it, one kept closed by a spring, which the oil forces open as it goes into the vaporiser ; the other is also kept closed by a spring, and should the engine run too quickly, the governor J opens it and allows some of the oil to run back to the tank. This valve can also be opened by turning the little regu-

lating handle provided, which will stop the supply of oil to the vaporiser, and thus stop the engine. The action of the engine generally may be explained as follows :—

The vaporiser having been previously heated, and the fly-wheel being pulled round, the first out-stroke of the piston thus made will cause the air to be drawn into the cylinder, and at the same time the pump will force oil into the vaporiser, which is immediately transformed into oil vapour by the heat of the vaporiser. On the return stroke of the piston the air is compressed into the vaporiser and thereby mixed with the oil vapour, and just as the piston gets to the end of its stroke an explosion takes place, which forces the piston out on its second out-stroke ; when the piston gets to the end of this stroke the exhaust valve opens, and the return stroke expels the gases, the same cycle of operations being repeated continuously.

The speed of the engine is governed by a small "Porter" governor, which acts through levers on an overflow valve fitted in the valve box X attached to the vaporiser, so that when the engine runs too quickly this valve is opened by a governor, and the oil allowed to return to the tank instead of going into the vaporiser ; the vaporiser getting little or no oil, the speed of the engine is thus regulated.

The oil used for running these engines can be varied from oil of a specific gravity of 8, and in some cases to 88, and with a flashing point of 200 to 250° F.

These engines have already been largely manufactured and sent to all parts of the world, being used for almost every purpose for which power is required. They will drive a dynamo for incandescent lights as steadily as any steam engine.

Fig. 195 shows a sectional view of the engine, and Fig. 196, sections of the cylinder with its vaporiser, and of the air and exhaust valves, which are both operated by levers from the side shaft cams.

The Roots Oil Engine is shown in two views, Figs. 198 and 199. It uses the cheapest sorts of paraffin or kerosene oil for both the cylinder and ignition. It is claimed that owing to the construction of the vaporiser the complete mixture of air

oil produces perfect combustion, so that there is much deposit on the cylinder walls than with other engines, they therefore frequently run six months without requiring aning. The piston is constructed to contain a chamber sed by rings in which any escaping oil vapour is trapped condensed, so that the engine gives off less smell than ers. The engine has the "Otto" cycle, but with a double plosion impulse as described on p. 175.

The Trusty Oil Engine.—This is an engine that has been

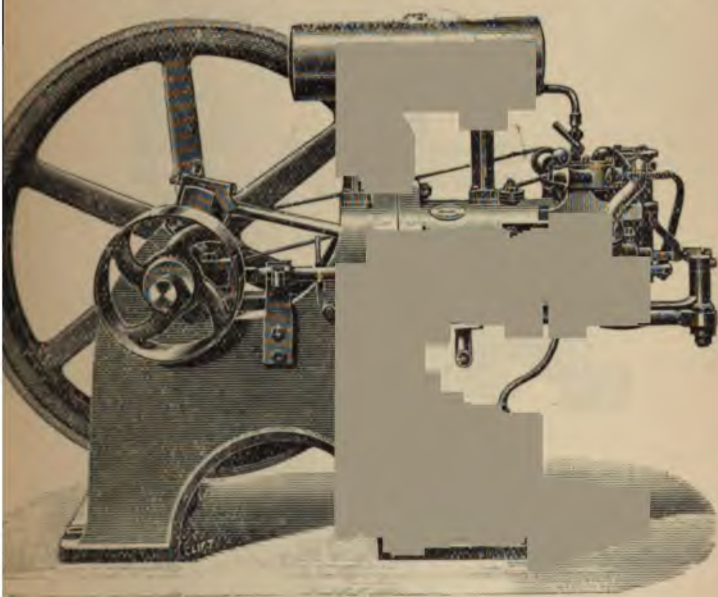


Fig. 198.

signed for using the common oils, such as petroleum and ordinary lamp oils, but creosote and the heavier oils can used.

It is an engine upon the four-cycle principle, that is, an pulse is obtained every other revolution: no other principle ll give as good results. There is the engine proper, a small pump and a vaporiser, the latter being placed at the end of cylinder.

The oil is poured into a small tank which is separate from e engine, and can be placed in any convenient position in

the engine-house; this is connected by a small pipe to the small pump which is actuated by the governor of the engine.

As the engine requires it, a drop of oil is pumped automatically into the vaporiser, where it is vaporised, and as the engine draws it into the cylinder, air in excess is also drawn in through a separate valve. Upon the charge being compressed, it is fired by an ordinary ignition tube, which is kept hot by means of a small blow-flame, no electrical apparatus

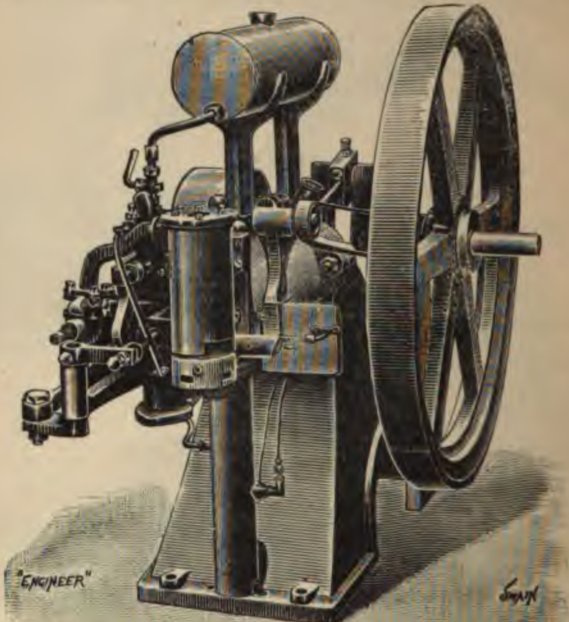


FIG. 199.

being required; there are thus no complicated or intricate parts, the whole being in view, and easily looked at or taken to pieces.

To start the engine the vaporiser is first heated, which takes about ten minutes, a few drops are pumped into the vaporiser, and by turning the fly-wheel once or twice the engine starts; the starting is in no way uncertain. When started, the engine will run for hours without attention, and, if

necessary, day and night. The engine can be placed in the hands of any intelligent man and be perfectly relied on.

The consumption of oil is about ½ pint per I.H.P. per hour. It has no red-hot vaporiser or spray-maker, and does not gasify the oil, but converts it into vapour.

The makers (Messrs. Weyman & Hitchcock, Guildford) make a speciality of two-cylinder launch, tramway and portable engines on this plan, having cooling tanks in combination or replacing them with circulating pumps where the water can be obtained from a pond or stream.

CHAPTER XI.

GAS AND OIL ENGINES. EXHAUST BOXES, SELF-STARTERS, ETC.

Exhaust Boxes, Silencers and Exhaust Pipes.—Nearly all gas and oil engines are supplied with exhaust boxes, which are simple, strong cast-iron vessels fitted with a manhole and cover, inlet and outlet flanges and a drain cock. Strength is necessary because they sometimes get filled with gases and explode by sparks or flame from the exhaust pipe. Water is condensed in the exhaust box from the burnt gases, and oil and soot collect also, so that they should be periodically drained and cleaned out.

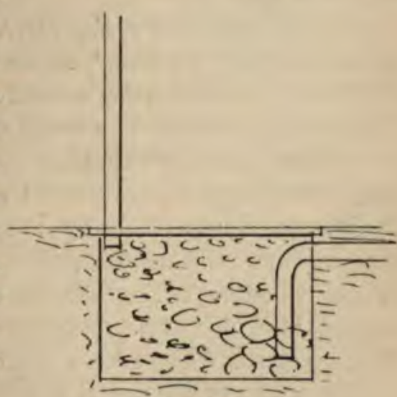


FIG. 200.

Various methods of silencing the exhaust discharge are adopted. One method is to provide a box, barrel or pit (Fig. 200) filled with coarse gravel or broken stones, into the bottom of which

the exhaust pipe is led from the exhaust box, taking care that its outlet is among large pieces of stone or other material so that it is not choked. A waste pipe is then led up from the top of the box or pit to any point where the gases may be discharged silently without constituting a

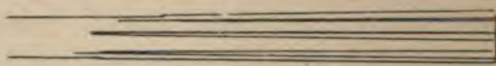


FIG. 201.

nuisance. Another plan is simply to split down the top end of the exhaust pipe by saw or chisel, as Fig. 201, about 3 feet down the pipe; this causes a gradual dispersion of the exhaust and greatly reduces the noise. A large pipe will be less noisy than a small one. Bends and elbows should be avoided as much as possible, the gases strike them and soon cut right through.

Self-starters are now frequently used with the larger sizes of gas and oil engines; the labour of pulling them round to obtain an initial explosion is often very great, especially when they begin to get out of order and give more than ordinary trouble in starting.

Fielding and Platt's Self-starter.—A feature of great importance in the "Fielding" engine of large powers is the very efficient system of starting recently patented by Mr. Fielding. The new gear consists of a small reservoir of about the size of the cylinder jacket, which, after the engine has been started, is kept charged with compressed air at a pressure of about 50 lbs. per square inch by the engine itself when being stopped, thus utilising the power stored up in the fly-wheels for use when restarting the engine. It is, however, by the method in which this compressed air is employed that the Fielding starter offers such a great advantage.

The action of starting is as follows:—

The crank being placed slightly in advance of the dead centre nearest tô the cylinder, gas is admitted by a small cock to the combustion chamber, from which the air is allowed to escape at a small pipe terminating in a jet near to the top of

he ignition tube Bunsen chimney; this is also provided with stop cock.

When the air is driven out and the gas begins to escape at the jet, it becomes ignited, and as soon as it burns with a steady flame, showing that an ample supply of gas is present in the cylinder, the outlet and inlet cocks are closed; compressed air is then turned into the cylinder and, the igniting valve being open, as soon as an explosive mixture is formed and a sufficient pressure attained, the charge is ignited by the igniting tube and the piston is driven forward with a very powerful impulse, the ordinary cycle at once coming into operation.

This method of starting is so powerful that an engine can be started with partial load on, and practically dispenses with the use of fast and loose pulleys or friction clutches.

The arrangement is exceedingly simple and can be managed by any ordinary unskilled labourer with ease, and in all respects is so satisfactory that it leaves little to be desired.

Independently, however, of the starting gear, a Fielding engine of 100 I.H.P. can be readily started by hand by three or four men, in fact an engine of this size has repeatedly been started by hand by two men only.

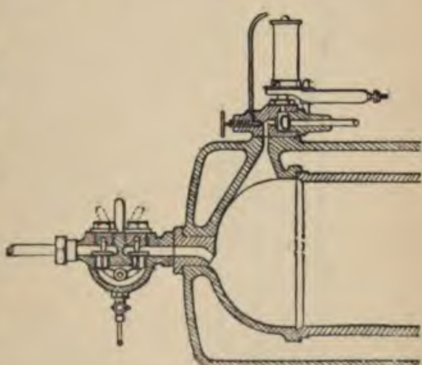


FIG. 202.

This, however, is only required in the rare event of the reservoir being exhausted; when charged there is sufficient storage to enable the engine to be started from six to a dozen times without recharging.

As compressed air only is stored there is no risk of an explosion taking place, and the valves are not liable to corrosion from the storage of spent gases as in some starters.

Fig. 202 shows a section of the Fielding self-starter. The engine is of the usual four-cycle construction, but with the hot

tube ignition on top of the cylinder having a timing valve. Fig. 203 is a diagram from this engine.

The Stockport Self-starter (Fig. 204) is similar to the

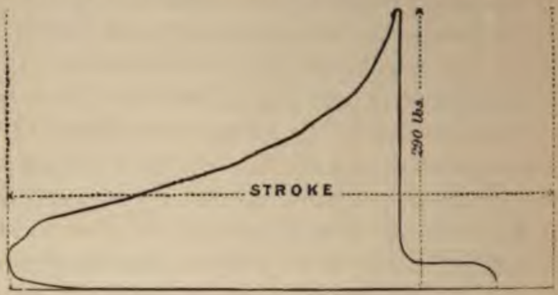


FIG. 203.

last, but without the compressed air addition. The crank is pulled over on the forward stroke to about one-third

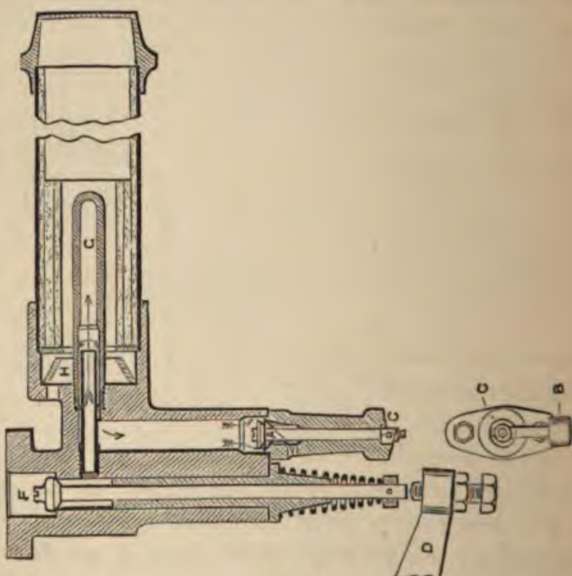


FIG. 204.

the stroke, the cylinder drawing air only. Then by a small pipe gas is turned on into the cylinder, and the mixture

flows out by a small vent at the top of the ignition tube; both gas and vent holes are fitted with valves closing outwards, so that as soon as the mixture becomes explosive it fires, closes the two valves and drives forward the piston. The main gas cock is then opened to supply gas to the engine. The ignition tube here employed is one of composition metal of small size, and is arranged so that the gas and air mixture can at each ignition blow out some of the products of combustion remaining from the ignition. This is effected by the small annular passage for the air and gas mixture between the inner and outer tube, as shown in the section, in which A is an outlet valve, shown in position for the first starting impulse. At F is a valve past which air is allowed to flow from the cylinder as forced out by the incoming gas, which is admitted to the cylinder by a special gas cock. When the admission of gas into the air at the end of the cylinder has made a sufficiently strong mixture, it is exploded by the ignition of that which passes to the ignition tube through the valve F. The explosion closes the valve A, and it is then kept closed by the weighted lever B acting on the inclined surface C, shown. The valve F is not air-tight, a small groove being made in its face, so that there is a slight escape at each stroke of the engine, just sufficient to cause some of the products of combustion to be drawn by induction out of the ignition tube, and its action thus made more certain. The timing valve F is operated by lever D and a cam on the cam shaft, compression taking place during only about $4\frac{1}{2}$ inches to 5 inches of the stroke.

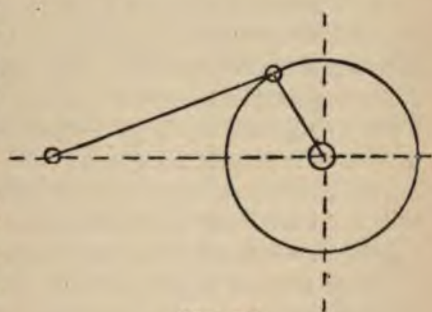


FIG. 205.

Instructions for working the self-starter.—1. Light Bunsen burner H, to heat ignition tube G, and see that it burns with a clear smokeless flame.

2. Fill all lubricators and oil necessary parts of engine, putting trimmings in oil pipes.

3. Turn engine on impulse stroke, with crank on top or similar position to sketch, Fig. 205. (When engine is on the impulse stroke, ignition valve is full open and all other valves closed.)

4. Move bowl on exhaust lever to end of stud, to gear with double part of cam.

5. Before admitting any gas to engine, re-examine Bunsen flame and see that ignition tube is a bright red heat.

6. Expel any air out of the gas pipes and gas bag (a small cock or plug in gas pipe or gas bag close to engine is useful for the purpose), fill gas bag, and when full, turn gas tap completely off or partly off, as may be found best.

7. Then open valves of self-starter, the one for gas inlet on the exhaust valve box and the outlet on end of ignition tube G. These valves are opened by unscrewing the brass milled nuts and raising the small automatic closing catches.

8. Gas being now admitted through self-starting valves, will after a short time (say one minute for coal gas and three minutes for fuel gas) cause the engine to start.

9. When engine has made four or six revolutions, gas bag should be filled and gas supply to engine to be left full on. (This operation, however, may vary according to pressure, quality of gas, or position of gas bag relative to engine. It may be found that engine will start better with gas tap open, partly open or closed. One or two trials will show the best method.)

10. Bowl on exhaust lever may now be moved to working part of cam, and milled nuts on starting valves gently screwed down.

Engine will now be in full running order.

In the event of engine failing to start automatically, care must be taken to prevent any accumulation of gas about engine, or in engine-room by leaving gas taps turned on and engine stopped in any other position than that arranged for, by having mark "O" on side-shaft at top. In such cases where difficulty in starting arises, when nothing apparently is wrong with engine, it is generally policy to close starting valves altogether, and effect a start by pulling engine round by hand. Or, see that the fly-wheels are turned by hand several times to remove all gas from cylinder, and to get nothing but air in cylinder, then try self-starter again.

Men should be careful never to climb on fly-wheels or put them-

selves in any other dangerous position, and the instructions here given should be carefully followed.

When engine is first erected the moving parts will be somewhat stiff and may interfere with the self-starter acting; this will be remedied when engine has been running some little time.

Tangye's Self-starter is a hand pump which is used to force gas and air into the cylinder space formed by setting the crank forward to about half stroke. The timing valve, which regulates the ignition period, is first closed by a wedge, and when the mixture has reached the required pressure, which is indicated by its escaping from a spring relief valve, the wedge is withdrawn and the charge, entering the hot tube, fires and starts the engine.

The Clerk-Lanchester Self-starter (Fig. 206) is employed by Messrs. Robey & Co. on their gas engines. It consists of a separate strong cast-iron mixing vessel of a conoidal form, and capacity rather greater than the cylinder, to which it is connected by a pipe and check valve, the latter opening towards the cylinder. The crank is set at about 15° forward stroke, gas is turned on to both the mixing vessel and cylinder by two pipes from one valve, while a jet of gas, which is kept burning just above a small vent at the top of the mixing vessel, lights the mixture as it flows out as soon as it becomes combustible. The gas tap controlling the admission to the cylinder, air vessel and jet is then closed, when the flame at top shoots down into the charge, fires it, and forces the gas into the cylinder under pressure, at the same time exploding it.

The action is as follows:—The check valve is released by its clamp Z when stopping, the engine then, while slowing down, sucks the starter chamber free from products of combustion, air entering through the igniter nozzle Y. In order to start, gas is allowed to flow in through the pipes J and J, forming mixture in the coupling pipe E and chamber A; a portion of this issuing from the nozzle Y becomes ignited, the supply cock X is then turned off and ignition passes into the chamber A. The first portions of the charge ignited expand, pushing a body of mixture past the check valve W

into the cylinder of the engine and increasing the pressure therein; this is closely followed by the advancing flame, and thus in a fraction of a second the combustion space and

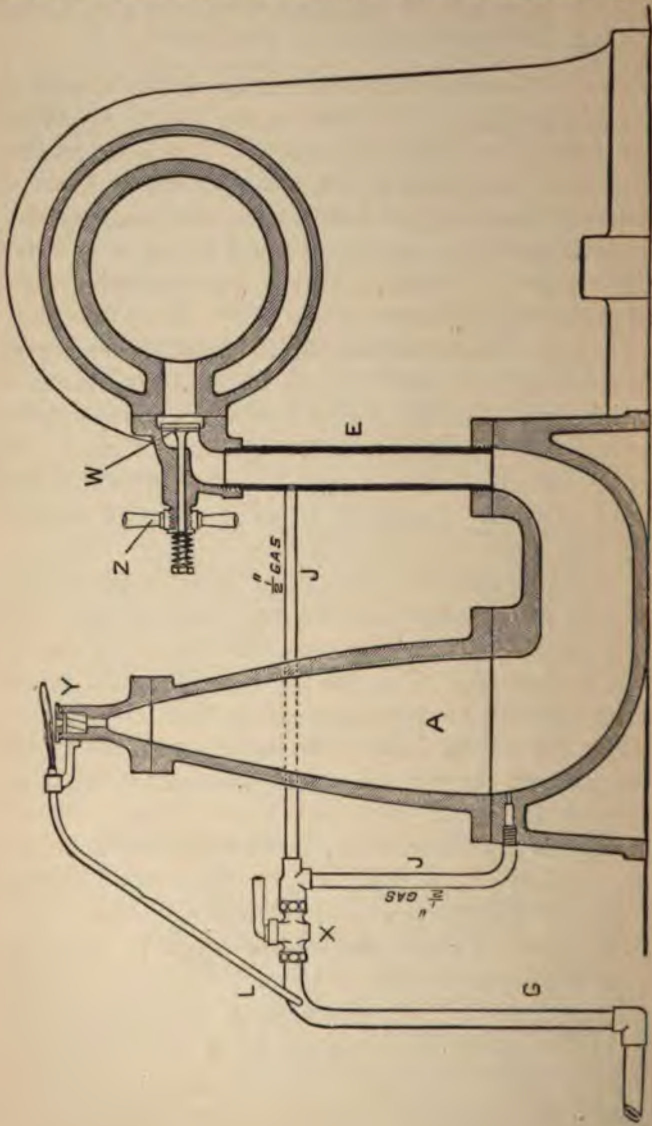


FIG. 206.

der of the engine have been charged with compressed ure and ignition effected. Immediately the flame passes alve W, the rise of pressure in the cylinder closes the said e and starts the engine. The clamp Z is then turned to the valve.

These starters are made as independent accessories, capable ttachment to any gas engine with the "Otto" or other e, and are applied to large engines up to any power. h this starter it is claimed that an engine can be started full load on by obtaining an initial explosion of high gy in the vessel A.

The Lanchester Self-starter (Fig. 207) is a very simple ratus that can be attached to any engine of the "Otto" e. It consists of a small gas attachment governed by a

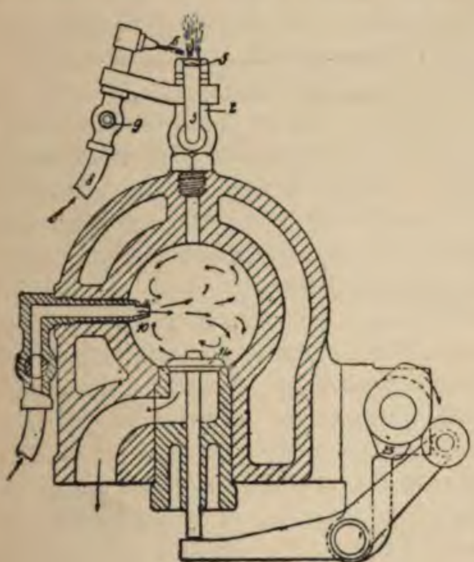


FIG. 207.

which admits gas at the ordinary gas pressure into the der of the engine, the piston having been moved so that rank is about 60° past the in centre on the forward or im- stroke; the space behind the piston is then filled with

air, which, when the gas is turned on, is driven out at a nozzle fixed on top of the cylinder, governed by a cock and fitted with a small gas jet, which ignites the outrush of gas and air as soon as it becomes inflammable; at this point the gas supply is shut off; this causes the flame to pass back into the cylinder and explode its contents. After this first impulse the engine will usually run by itself; but several less violent consecutive impulses can be obtained as follows:—A relief cam is arranged to keep the exhaust port of the cylinder open until the piston has completed its compressing stroke. The engine is started as described above, and after exhausting the products of the first explosion draws in a fresh charge, a portion of which, on the return or compressing stroke, is forced out through the exhaust port and through the nozzle of the starter. As soon as the piston pauses on the crank crossing its centre or commences its working stroke, the explosive mixture ceases to pass through the nozzle of the starter or reduces its rate of passing through, and the flame passes back into the cylinder and explodes the remaining portion of the charge therein. A series of explosions may be obtained in this manner. When the engine has attained a sufficient speed to overcome the resistance of compression, the auxiliary cam and the starter are thrown out of action and the engine works in the ordinary manner.

Indicating is very desirable in gas and oil engines as an infallible test of the efficiency of an engine, and is not so often resorted to as it should be. Nearly all engines have a screw plug for the purpose of attachment of the indicator. One of the high speed types should be used, and in any doubtful case the diagram will show the origin of any faults that may be giving trouble; or at all events show whether the engine is doing a fair amount of work for the gas consumed.

The diagrams from compression engines are generally of the following form when in good working order (Fig. 208), and the indications of irregularities are these:—(1) Insufficient compression (line A indicates that the exhaust valve, the slide or piston leaks). (2) Slow ignition, lines B B show that

nition is too late, either from insufficient gas in the mixture, r in the case of hot tube ignition, from the heated part of the ube being too far up. In the former case more gas must be iven, and in the latter case the position of the Bunsen flame equires lowering nearer to the junction of the tube with the cylinder plug.

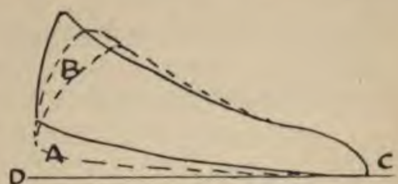


FIG. 208.

The point C of diagram should reach the atmospheric or zero line D, thus showing that the exhaust is free from back pressure.

FIG. 209.

Non-compression engines give a diagram like Fig. 209 when working well, in which, with the exception of the compression line being absent, the other points are similar to those of the compression type. In consulting a diagram the speed must be taken into account, as with high speeds the explosion curve approaches the form of one of the lines B.

When the engine is leaking badly, the explosion line B will not reach as high a pressure as should be the case if sound and tight, thus giving weak impulses.

SECTION III.

WIND MOTORS AND AIR ENGINES.

CHAPTER XII.

WINDMILLS AND TURBINES.

THE oldest device for utilising the force of the wind, the windmill, is still a serviceable motor, and, in fact, is coming to the front again by reason of the great improvements recently made in it. Many novel forms of wind motors are used in America and the colonies, but as yet their chief use is that of pumping water for supply of dwellings and factories, draining and irrigation. They have been used for flour mills from time immemorial, and find some few other openings in farm work, driving chaff-cutters, turnip-slicers, bean-crushers, &c. For general manufacturing purposes it is almost impossible to apply them directly, as their motive power, the wind, is too uncertain and erratic; but they can be used to pump water into a storage reservoir at uncertain intervals: the water to be used in working a water motor of some kind at more regular intervals.

Wherever used they are the cheapest motors available; will run twenty-four hours per day if the wind serves, and adjust themselves to its varying moods.

Windmills of the old type, with wooden sails, are picturesque but clumsy; the wooden construction of sails has given place to metal.

It is to be regretted that the old millwright and his sphere of labour is dying out and becoming swallowed up by the modern system of specialisation of work. Nowadays

every workman knows his particular branch and tools and no other. If a fitter wants a hole or two bored in a piece of wood, or an end sawn off, he sends for a carpenter or pattern maker, and stands by while the job is being done for him; and so with ali other trades. But the millwright was trained to handle every sort of tool needed in fitting up a mill or factory, and, but for his indifference to theory and clinging to old thumb-practice, was a far better and more intelligent all-round workman than the modern fitter and erector.

The windmill and flour grinding plant was one of his jobs, and though often rough, was always substantially and—generally—conscientiously built; but there is little in the construction to interest the modern engineer. The sails and arms are simply a matter of plain woodwork, bolts and plates. The gearing, however, needs occasional attentions; the chief of which are new bearings and recogging mortise-wheels, with now and then a new cast-iron wheel or pinion. Horn-beam is generally preferred for wheel cogs, and the method of cutting them is to leave the tooth point rough till all have been driven in; then mark the pitch line, plane off the faces and ends, and mark each tooth at both ends from a templet, to which marks they are then cut down. The large wheels are frequently built in segments, which need chipping or planing at the joints, for which a templet should be made to fit the joint. Patterns for these wheels and other castings are usually kept at the mill, and the new work got ready before stopping the mill for repairs. Crown wheels and others are commonly staked to square or octagonal shafts: a much more difficult job than keying up on a turned shaft with a bored wheel boss. The four keys or stakes must be fitted so as to carry the wheel round without wobbling, and the spaces between the stakes are usually filled with oak wedges tightened up by wrought iron or steel ones driven in amongst them. The best plan for this is to secure the wheel temporarily by wood keys driven in the spaces between the stakes, wedging them so that the wheel runs true on the pitch line previously marked round. Then fit the stakes to their positions and mark them.

The shafts are often very rough, neither straight, round or square, only the journals being turned; rough timber supports and clumsy pedestals provide no opportunities for display of skill or workmanship.

Modern windmills are constructed entirely of metal, the wheel being raised and supported on a light and well-designed braced wrought-iron framing, the columns of which are either wrought-iron tubes, L, T, or [iron, tapering at top, where they are secured to a cast-iron head on which the running gear is fixed. A cast-iron base ring carries the feet of the columns, and the driving shaft runs down the centre, with bevel gear at top and bottom to convey the power from the wheel shaft to wherever needed. If for pumping only, a crank on the wheel shaft overhead is connected by a rod direct to the pump, fixed immediately under the framing at the depth required; but two or three rods and pumps are better to balance the action. A clutch and lever gear connect the motion for varying the angle of the sails with the wheel, so that it can be operated from the ground; and a fly vane in the rear of the wheel carries it round to face the wind. Governing gear is attached to some of these wheels to regulate the speed to some extent.

FIG. 210.

Wind turbines are similarly constructed, but the wheel is formed of sheet steel blades of spiral form, each blade being part of an arithmetical spiral, and set at an angle to the plane

of rotation. These are used chiefly in South America for pumping purposes (Fig. 210).

The chief attention these all require is lubrication and protection of the working parts from the weather. All the ironwork should be galvanised and afterwards painted; the gearing examined occasionally, and brasses and bolts adjusted.

The size and power of windmills are rather indeterminate; only an approximation can be made: multiply the area of the sails in square feet by the tabular pressure of the wind and by the velocity in feet per minute, and divide the quotient by 33,000 for the horse-power; the actual horse-power will be about one-half of this result; and in calculating the power as applied to a pump or to gearing, the radius at which it acts must be taken as that of the centre line of gravity of the sails, and the speed at this radius at about one-half that of the wind.

WIND TABLE.

Miles per Hour.	Feet per Minute.	Force in lbs. per sq. ft.	
4	352	0·079	Gentle breeze
6	528	0·177	
8	704	0·315	Pleasant brisk gale
10	880	0·492	
15	1320	1·107	
20	1760	1·968	Very brisk
25	2200	3·075	
30	2640	4·429	High wind
40	3520	7·873	
50	4400	12·300	Very high wind
60	5280	17·710	Storm
80	7040	31·490	Hurricane
100	8800	50·	Tornado

Fixing.—A good foundation is essential, as the overturning effort of the wind on a large sail mounted at a considerable elevation is very great. The foundation need

not be expensive; one of the best and simplest is the Earth Screw (Fig. 211) for country situations in ordinary ground. Another plan is to drive four or more piles in a circle and bolt cross-bearers to the heads of them just above the ground

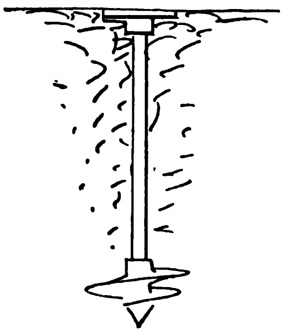


FIG. 211.

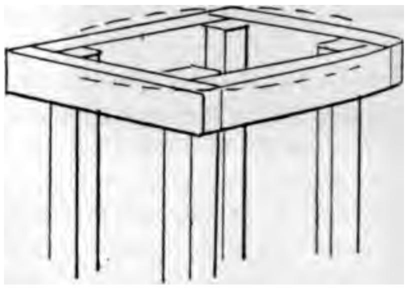


FIG. 212.

(Fig. 212), the base of the wind wheel standard to be bolted to the bearers. Where rock exists, bolts may be sunk in holes jumped in the rock and filled round with cement.

Small windmills are used frequently on board ship to pump the bilges.

CHAPTER XIII.

FANS AND BLOWERS.

Blowing Machines: Bellows.—Several forms of these are largely used. Many blacksmiths still prefer them for their fires, but in works of any size they are invariably absent and fans or rotary blowers used. A serious danger with them is the risk of the gases from the fire leaking or travelling back into the bellows while standing; this is followed by a violent explosion as soon as the bellows is started again, which generally either bursts the leather or the top and middle boards, and involves a very substantial repair. There should

: a proper check flap valve in the pipe in all cases, especially the bellows is fixed at a higher level than the forge fire. ortable forges use the circular parallel bellows placed below ne fire-box, but the latest types employ small fans or rotary lowers, which give good results. Repairs to the leather ribs can be handed over to any good saddler. A split board can be repaired by a large piece of $\frac{1}{8}$ inch wrought-iron plate, fastened on with a thick coat of tar between and plenty of screws used. The leather should be well greased with horse grease at intervals of about six months to keep it supple. The suspending pins fixed to the middle board are seldom a good job and work loose, often splitting the edge of the board; in this case a strap should be forged with the pin formed on it, and well screwed along the edge of the board.

Fans and Air Propellers.—A well proportioned and well fitted fan will run almost silently, and the worse the design and fitting the greater the noise. The maximum useful effect of fans cannot be obtained unless they are run at high speeds; the peripheral speed should be $= \sqrt{\text{Press} \times 97{,}300}$. They have no positive push such as a rotary or cylinder blower, therefore depend on centrifugal action. Fans, like centrifugal pumps, take air at the centre and deliver it by centrifugal force at the periphery, where it is led by a apering clearance space into the delivery pipe.

Air propellers are not centrifugal, their blades are so haped, and placed at such an angle to the plane of revo- ution as to neutralise any centrifugal action induced by the evolution of the wheel, so as to drive the air at right angles o the plane of revolution, like a reversed turbine or screw ropeller. They are not constructed for pressure, but for elivering large volumes of air at very low pressures. Fans re similarly used but are serviceable at pressures up to 1 or lbs. per square inch; for higher pressures positive blowers f the rotary or cylinder types are used.

The bearings and their efficient lubrication are of greatest noment in these machines; they should be long, at least hree times the diameter of the spindle and well fitted, the endency being by continued rapid vibration, first to loosen,

then wear rapidly. Small fans often have only conical pivots, which give a great deal of trouble; they should have a centre hole drilled down the brass bearing and oil way led into it, as Fig. 213, and will run much better in this way. The brasses should always be bolted down hard (see p. 78), and the bolts fitted with lock nuts, as they soon get loose. For blowing cupolas or blast furnaces of any form it is imperative that the fan be reliable, as a stoppage in the middle of a blast might entail partial destruction of the furnace. Fans are also used for stive rooms of flour mills, winnowing, for forced draught and other purposes.

Rotary Blowers and Exhausters are very largely used for blowing furnaces and fires of all kinds, being positive in action; they will work up to pressures of from 3 to 10 lbs. per square inch. Furnace blasts are, however, rarely higher than 2 lbs. per square inch; with heavier pressures the fire-brick linings burn out rapidly and the consumption of fuel becomes out of proportion to the increased rapidity of melting. They consist of revolving vanes, sectors and other forms of internal pistons in a cylindrical or double cylindrical case, sections of some of the best known of which are shown in the 'Engineer's Sketch Book,' pp. 161–164.

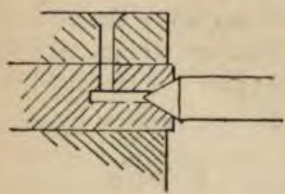


FIG. 213.

The geared types of blowers have a pair of equal spur gears to connect the motion of the shafts, and are usually driven by two straps, one open, the other crossed, one on each shaft, but at opposite ends; the speeds are high and they are decidedly noisy. Powdered blacklead or blacklead and grease are lubricants applied to the internal pistons and case, and the air inlet is protected by gauze to prevent chips, &c., being drawn in with the air. As with fans, the bearings require careful attention and well oiling, but being very long will last with proper care many years. They should be bolted down solid and have lock-nuts fitted to the bolts to prevent shaking loose. White metal is a good and serviceable

g for these high speed bearings, or phosphor bronze may ied with success. They are frequently fixed in wet or situations, and in consequence wear rapidly. Roots' Baker's blowers both have means of renewing the rubbing of the vanes or revolving pistons, these parts being 'ood and not difficult to repair. A templet should be of the curve of these parts, to which the new faces can

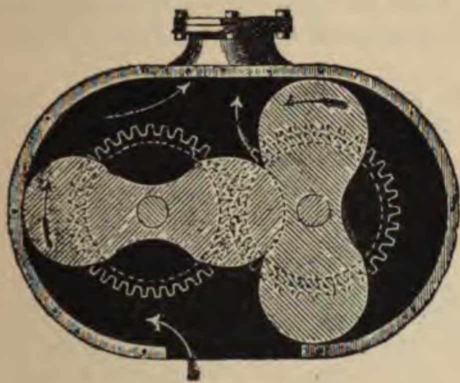


FIG. 214.

planed down, but with the later patterns these faces are e up by composition as described below. Unless these a fairly good fit to one another and to the case (but out rubbing hard) a great deal of air will slip past them, cially with the higher pressures. End play must be ded for the same reason. Fig. 214 shows a section of ts' blower as commonly made.

Directions for fixing and running Roots' Patent Improved vers.—Care must be taken in fixing the blower that the roller s are set level in both directions.

The blower should be fixed in a place properly covered in, and subject to any great variation in temperature, and care should cially be taken to have it at all times well protected from the her, so that damp or wet cannot affect the internal parts of the ine. When the blower is supplying blast for smiths' fires an e valve is necessary to allow the surplus blast to escape, if it

should happen that all the smiths' fires are shut off, and the blower is still running.

All the friction in the operation of the blower is confined to the journals and the cog-wheels. These should be oiled daily when the blower is in use, with the best quality of lard or sperm oil, avoiding all lubricating compounds. There is no friction whatever in the internal working parts of the blower.

The blower should at all times be in such a condition that when the straps are taken off the machine can be easily turned round by hand, not sticking, or harder to turn in one part of the revolution than the other.

The driving pulleys on counter shaft must be exactly the same diameter, and the driving belts should be in equal tension, so that each belt does the proper amount of driving.

Cast-iron air-tight pipes, tuyères, and shut-off valves are *absolutely*

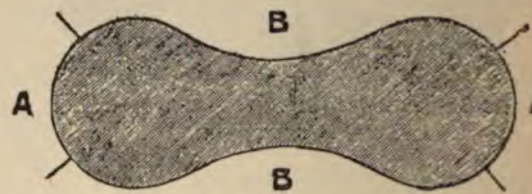


FIG. 215.

necessary. All joints should be perfectly air-tight. This applies in all cases, but more especially it is necessary for blacksmiths' fires and melting iron in cupola.

Directions for re-coating Roots' Patent Blower with composition.—The internal rollers in the blower do not quite touch each other when in motion, but they work as close together as possible without actual contact. These rollers are coated with a composition. They only require to be done at long intervals (say every twelve months). For coating, melt the composition, and when sufficiently cooled, put it on the rollers with a brush, but only on the parts that show not to be in contact; after this the machine should be set in motion for a short time, then examine the rollers, and those parts that show not to be in contact should be done over again, until both rollers work quite close and practically air-tight. In coating, care must be taken to scrape all composition off the tops of the rollers A A, Fig. 215, and only to put it on the hollows and sides B B. Before re-coating

PARTICULARS OF ROOTS' PATENT IMPROVED POWER BLOWERS.

Number of Blower.	Melting Iron. Maximum Number of Revolutions per Minute.	Melting Iron. Tons of Metal per Hour.	Melting Iron. Adapted to Cupola Diameter inside of Lining.	Number of Blacksmiths' Fires.	Approximate Nominal Horse-power.	Volume of Blast delivered in one Minute.	General Dimensions. Diameter of Delivery Orifice.	General Dimensions. Diameter of Pulleys.	General Dimensions. Breadth of Pulleys.	General Dimensions. External Dimensions. Length.	General Dimensions. External Dimensions. Breadth.	General Dimensions. External Dimensions. Height.	Approximate Weight.
			inches.			cubic feet.	inches.	inches.	inches.	ft. in.	ft. in.	ft. in.	cwt.
No. 2 A	350	½	14	4	¾	600	5	8	2½	2 4	2 8	2 7	4½
No. 1 A	350	¾	16	6	1	800	6	10	3	2 6	2 8	2 7	6½
No. 1	400	1	16 to 24	10	2	1,300	7	10	3	3 4	2 8	2 9	7½
No. 2	400	2½	24 ,, 30	18	4	2,000	8	12	3¼	4 6	3 0	3 0	10¾
No. 3	380	4	30 ,, 36	30	6	3,000	10	14	4	5 8	3 0	3 2	14¼
No. 4	350	7	For two or more Cupolas and fitted with extra Bearings.	50	8	4,550	12	16	5	7 9	4 0	3 9	26
No. 5	320	10		70	10	6,400	13½	18	5½	9 3	4 0	3 11	30
No. 6	310	15		90	12	8,680	17	20	6½	9 6½	4 11	4 10	47
No. 7	300	20		120	14	10,800	19	22	7	10 6	4 11	5 0	57

the internal rollers the bearings of the shafts must be examined, and if they are much worn they should be rebushed with special phosphor-bronze bushes. When re-coating the internal rollers, all the old composition and dust which has adhered to it must be carefully scraped off. The new composition will not stick on the old. If too much composition is put on it will cause the internal rollers to rub hard upon each other. When this is the case the rollers should be slightly eased at the part shown hard in contact.

This composition only requires to be warmed up and melted, not to be raised to anything near boiling point.

Blowing engines are used for all pressures, the blowing device being a cylinder and piston; they are, therefore, strictly speaking, air pumps. For blowing blast furnaces, steel converting plant, &c., they are of very large dimensions. A great many of the old beam engine type are still running, many with air cylinders up to 12 feet diameter, but the modern type is a vertical engine with crank shaft on the base plate—marine fashion—and the steam and blowing cylinders fixed overhead tandem-way. Batteries of three, four or six of these are now common for large ironworks. As regards the steam engine part of these blowing engines, there is little to specially mention, and the chapters dealing with steam engines (IV.–VIII.) may be consulted generally. There are one or two points, however, that may be first noted. A large fly-wheel is used to equalise the rotative energy, because at the first portion of each stroke the resistance rises from zero to the full pressure in a fraction of the stroke varying with the pressure required, while the steam is at full pressure in the steam cylinder. For a 7 lb. blast the resistance rises during nearly one-third the stroke, for 4 lbs. about one-quarter, and so on. The speed is about that of ordinary engines of the same dimensions, and the heating of the air by compression very small. Leather-faced flap valves are used with rectangular or grating seats arranged in groups. The clearances of inlet and outlet ports are not of much importance, as the loss by compression is small at these low pressures (see air compressors, next page). There are, of course, the same advantages to be gained by compounding.

as in other engines, and two or even three engines may be advantageously coupled to obtain a more uniform rotative energy with a light fly-wheel, but, as upon the reliability of these engines depends the working of the blast furnaces, and a breakdown that involves stoppage would be a very serious matter, there is usually a spare engine in readiness to start at any time. Blast cylinders are lubricated with powdered blacklead; the pistons have ring packings and rarely give any trouble. The velocity of air in air pipes should not exceed 35 feet per second.

CHAPTER XIV.

AIR COMPRESSORS AND COLD AIR MACHINES.

THE use of compressed air is extending; its convenience for many purposes where steam or gas power is inadvisable or impossible, the absence of heat, of waste heat or visible exhaust, with other conveniences for transmission, &c., render it particularly desirable as a source of power. We may divide compressors into two general classes, dry and wet. Cold air machines are air compressors combined with an air motor or air engine, the compressed air—after being cooled in a surface cooler—being then expanded, doing work in the air engine, which work assists the steam used in compressing, so that the nett loss is the internal friction + the heat absorbed by the surface cooler.

In compressing air to ordinary pressures, say up to 100 lbs. per square inch, the highest pressure in the steam cylinder, the steam being used expansively (Fig. 216), is opposed to the least resistance in the air cylinder and *vice versâ*; all the ingenious devices contrived by inventors to equalise these resistances have dropped out of sight, and reliance is now universally placed in a heavy fly-wheel as an equaliser, the weight and diameter of which must be calculated to take up and give out again the average differences of mean pressures

in both cylinders, as shown by indicator or theoretical diagrams. With a fly-wheel thus proportioned the steam cylinder may be compounded and worked to a low expansion effectively, and this is the system now being universally introduced for economy.

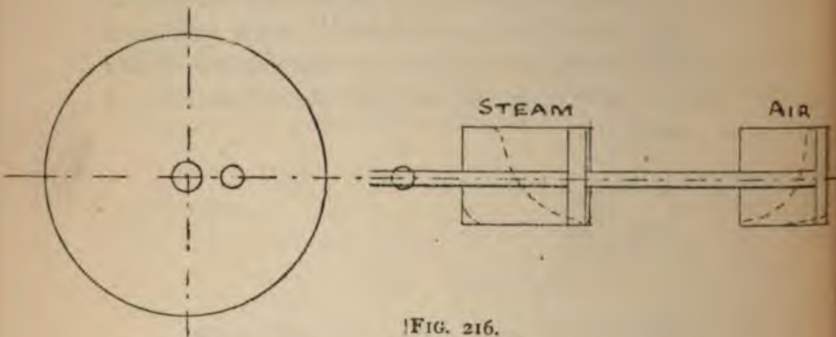


FIG. 216.

Dry compressors use no water in the air cylinder to cool it, but use water outside it as a jacket or tank. Wet compressors either have what is called a water piston—which is a body of water between the piston and the air under compression—or a water spray, which is injected every stroke and

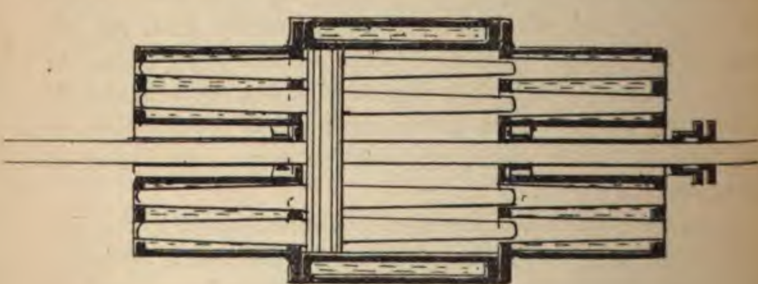


FIG. 217.

must be discharged by the delivery valve along with the compressed air. This in addition to the usual external water jacket of the dry compressor.

In compressing air to say 60 lbs. per square inch, it reaches a temperature of 265° in the air cylinder before the

elivery valve opens, and is therefore about 1·4 times the olume it would be if cooled to atmospheric temperature. This (·4) percentage is all loss, because a bulk of steam equal o it has been expended in compressing this increased volume of air, which, by cooling after entering the receiver or pipes, contracts in volume to 1. Effective cooling *in the cylinder* is therefore very important. Methods are now being introduced, by extending the cylinder surface, to effect this without water njection. The author's method being an adaptation of the surface cooler principle to the air cylinder (Fig. 217) in which he ordinary piston is fitted with a number of plungers, lightly tapered, which at each end of the stroke fit an equal number of tapered brass cooling tubes through which the air s forced in compression in intimate contact with the cold ubes, passing out of these tubes by large annular delivery alves (not shown).

Wet compressors give a great deal of trouble by corro-ion of the cylinder, piston, rings and valves from the presence f water, besides which the amount of cooling obtained is nconsiderable.

Hot air in bulk, as in a cylinder, is very slow in parting ith its heat; the best results have been obtained from spray ts injected during the latter half of the stroke, and with such rce as to distribute it as a mist among the air. But for any purposes dry compressed air is a necessity, or at any te a desideratum, especially for cold storage, as moisture the air settles as snow on everything exposed to it. Com-ressors with water pistons and wet compressors generally, ust also be driven at a slow speed to prevent injury to the vers and valves; dry compressors can be driven at any eed, but the actual speed obtained is reduced practically to at at which the air is only moderately heated, or an average ston speed of about 120 feet per minute for ordinary ressures.

Nearly all compressors are driven by a steam cylinder, d the horizontal form is that almost universally adopted, as pe drawings Figs. 218 and 219. If driven by a belt the y-wheel must be retained, and a very large pulley becomes

necessary. Gearing is sometimes used, as Fig. 220. A water wheel is also frequently employed to drive a compressor, in

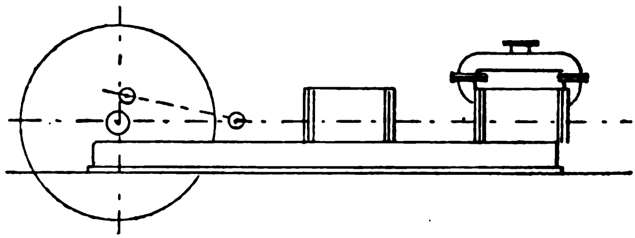


FIG. 218.

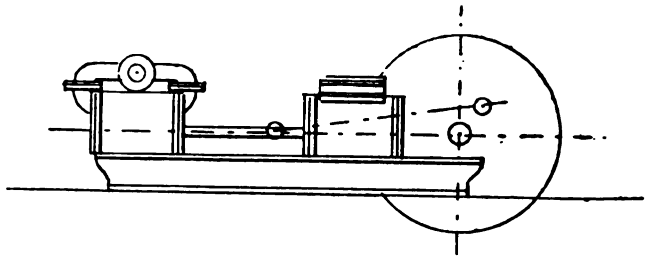


FIG. 219.

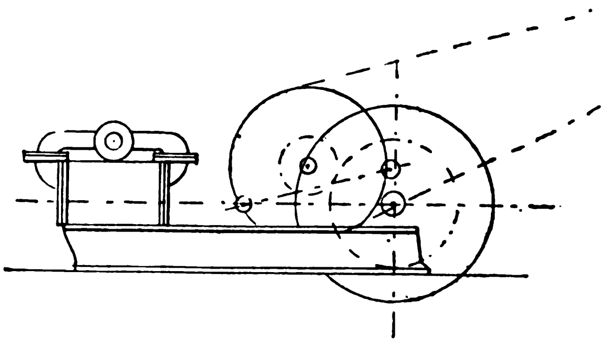


FIG. 220.

which case a connecting rod direct from the water wheel shaft is the best drive. For mining purposes, tunnelling, quarrying and similar work, where air compressors are used to drive

rock drills and boring machines, they should be very strongly made, as they are subject to much rough treatment by moving from place to place, and being generally fixed on a very temporary foundation. Where water is plentiful it should be allowed to run continuously through the water jacket or tank. In other cases the water must be removed as fast as it heats. Some large engines have circulating pumps to keep the water in motion, which greatly increase the efficiency of the water jacket.

For high pressures up to 2500 lbs. stage compression is adopted, and many patent cylinder combinations exist for these pressures, which are employed to compress oxygen, carbonic acid, nitrous oxide and other gases into steel bottles for manufacturing uses. This process is the compression of the air by steps or stages in two or three cylinders, decreasing in size; the reverse, in fact, of the compound steam engine. Between each compression it is cooled in a receiver, plain or tubular. At these high pressures the loss by heating is enormous, amounting often to 70 or 80 per cent.

At ordinary pressures the loss varies with the pressure and construction of engine and valves from 30 to 50 per cent.

Cylinders and Pistons.—These are invariably of cast iron, bored and turned as steam cylinders, &c. The pistons are fitted usually with cast-iron rings, but sometimes with phosphor bronze spring rings. Oil is the lubricant, admitted at the middle of the cylinder in horizontal engines. The clearances are very small, being a source of loss, because the compressed air not driven past the delivery valves expands again, assisting to drive the piston a short distance, but neutralising a part of the suction stroke. The piston must be maintained a good fit, and if water injection is used, brass or phosphor bronze rings and springs should be used, a brass-cased piston rod also, and brass valves and seatings. A good supply of oil will be needed as it washes out of the cylinder rapidly.

Valves and Seatings.—The valves must always be constructed so as to avoid ports or passages as far as possible, in fact any spaces that cannot be cleared of compressed air at every stroke; and for this reason the valves are almost uni-

versally arranged in the cylinder covers. The delivery valves are usually of brass or phosphor bronze, with guide spindles, and closed by springs, the seatings being either metal to metal or of vulcanised fibre. Inlet valves ought to have a positive opening and closing gear in all cases. Both spindle valves and Corliss valves have been employed for this purpose. If ordinary beating valves are used they are liable to flutter, besides which, as they must have springs to close them, there results a loss from a partial vacuum arising on the suction side, so that the cylinder does not fill completely with air at the atmospheric pressure. A small vacuum means a considerable loss in this way. Various patent and other devices are in use to prevent this. A similar positive motion cannot be given to the delivery valves, except to close them, because the point in the stroke at which they should open is uncertain, depending on the temperature, &c. The repair of these valves, springs, spindles and guides is the main outlay needed with compressors. It involves no special knowledge, but with the foregoing points borne in mind improvements can be frequently made in the effective working of compressors. Indicator diagrams should be taken occasionally from both cylinders, and the air diagram noted as to any vacuum occurring on the suction stroke (see A, Fig. 221) or return pressure due to clearances, as at B, or excessive stiffness of delivery valves, as shown at C. The mean pressure of the steam diagram, compared with that of the air diagram, will give the mechanical efficiency of the engine, from which must be deducted the increase of volume due to heating, as calculated from the delivery temperature.

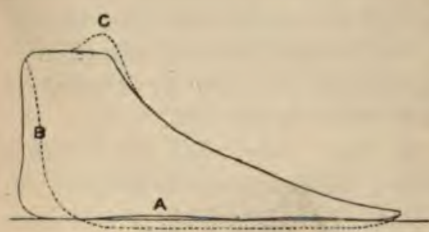


FIG. 221.

Receivers.—The compressed air is delivered into a receiver, usually a cylindrical vessel of boiler plate. A second-hand or spare boiler is often used for this purpose. With wet com-

pressors the water discharged with the air also enters the receiver and must be drained off, the best plan for which is one of the forms of steam-trap, not depending on temperature for its action. The mountings necessary for the receiver are safety-valve, pressure gauge, thermometer (if required), drain cock and stop-valve.

CHAPTER XV.

AIR MOTOR ENGINES AND HOT AIR ENGINES.

Compressed Air Engines.—Compressed air is used to drive air motor engines, rock drills, coal cutting machines, winding engines and pumping engines, besides some minor uses. Except for underground work, where heat is objectionable, the efficiency of these may be largely augmented by heating the air just before entering the cylinder by passing it through a coil over a furnace or gas heater of the Bunsen form. A temperature of about 300° gives double the volume of air, and therefore doubles the useful effect with a small extra cost for fuel. When the air is used without heating it gives a very cold exhaust, the moisture frequently freezing round and sometimes blocking the exhaust outlet. In cold storage rooms, into which cold exhaust air is conveyed for cooling meat, &c., the moisture contained in it is deposited as fine snow.

Heating the air before entering the air motor gets rid of this freezing difficulty, and the exhaust is discharged at a moderate temperature. Compressed air engines, rock drills, tunnelling machines, winding engines and coal cutting machines working in mines and confined positions use the air not heated, the cold exhaust being beneficial to the working place for ventilation and cooling.

Air motor engines are almost precisely similar to steam engines. The air can be expanded in the same manner, the cylinders compounded, and the same valves and valve gear used; but the cylinders do not need jacketing of any kind, or

drain cocks, and less lubrication than steam engines. The governing is the same for both. Heat is sometimes necessary around the exhaust to prevent its freezing up, and no exhaust pipe is necessary, the engine discharging its air into the atmosphere.

When the air is heated, and thus a higher temperature maintained in the cylinder, the lubrication must be effective and regular, as in the gas engine. An automatic lubricator is then the best to use. In all ordinary details the notes on maintenance and repair of the steam engine (pp. 51–86) apply to air motors.

Rock drills consist of a cylinder with reciprocating piston, to the head of which is attached the drill tool, having a rotary motion and a variable stroke; various special forms of slide valve or its equivalent are used, with tappet gear to reverse the piston and prevent it striking the covers. Several patented forms of rock drill are in use, one of which, the "Ingersoll-Sergeant" is well known. These machines are subject to very rough handling, and therefore are made entirely of steel, wrought iron, or malleable cast iron, with gun-metal or phosphor bronze details. They run at very high speeds, and being subject to a great amount of jar and hammering must be very securely built; bolts, keys and similar fastenings soon knock loose unless secured by lock nuts or split pins. There is considerable wear on the cylinder and piston, slide valve and tappet gear. The machine is provided with a handle to turn the piston and its drill on its axis when at work, also a screw to feed the cylinder with its piston and drill tool down to its work at the proper speed for cutting; and the machine stands on some sort of stand or frame with universal swivelling motion, so that the tool can be set to work at any possible angle. The steam or compressed air is led to the machine by a flexible pipe with screw union and stop valve on it. In working it is of necessity frequently moved about, and must be easy to handle and free from complication. Casualties usually result from rough handling, letting them fall on the rocks, &c.; in other respects the repairs are chiefly those due to wear of working

piston, glands, slide valve and tappet gear, which are easily dealt with, the drills themselves giving by far the most trouble. A set of these usually consists of about twenty, varying in length from 18 inches to 6 feet. The socket ends should always be turned to a templet to the taper of the socket, and if they get bent they should be trued up again in the lathe, so that they may always be revolved on their centre, when cutting in a hole, without wobbling.

Underground winding and pumping engines are worked frequently by compressed air, and as they do not differ essentially from those worked by steam, the same notes apply to them (see Chapter IV.), and air motor engines just described.

Coal cutting and tunnelling machines are similar in principle to rock drills, that is to say, they carry one or more tools, reciprocated by a cylinder and piston. The tools have adjustments for advancing and withdrawing them while at work, sometimes combined with a revolving motion. They are portable, but usually run by a carriage on a tram road, and can be set at any desired angle to work, and clamped securely by struts, &c., to the rocks. As with rock drills, their casualties most frequently arise from falls of rock, which break, bend or jam some of the working parts. The heavy jar and vibration of working loosens all fastenings. Sticking of the valves or gear may cause the piston to strike the covers and knock them out, or break the studs. The traversing screws sometimes break with the jar of the tool, which tends to crystallise the metal. Lubrication is often badly attended to, and clouds of dust and chips cause rapid wear and minor casualties.

Hot Air Engines.—Engines worked by the expansion of air by heat. There are two types: (1) those that take air at atmospheric temperature and pressure, expand it by heat, and after doing work in the engine, exhaust it at, or near, atmospheric pressure again; and (2) those that use the same body of air over again, alternately heating and cooling it. Of the numerous experimental engines that have been made by Ericsson, Stirling and many other indefatigable pioneers, only two or three forms survive. Of these, Rider's is perhaps the best known; it has two cylinders,

one of which is an air pump and draws air on one stroke, compresses it to about one-third its bulk on the return stroke, delivers it through a regenerator into the working cylinder, in which it is heated over a furnace, drives up the piston and is exhausted through the regenerator, some of its waste heat being taken up and transferred to the next charge, and so on. Stirling's engine is of the second type. The air is heated at the bottom end of a cylinder, drives up the piston, which, on descending, displaces the air, which passes to the top end and is rapidly cooled and reduced in volume by a water surface cooler. The next up stroke again displaces the air, which, entering the hot lower end of the cylinder, drives up the piston again. This is the simplest possible cycle with heated air, and probably the most promising and effective.

The faults of these engines are :—Great internal friction compared with available power ; burning out of the cylinder or heater bottoms ; large amount of lubricant needed ; very small power developed compared with the size of engine ; and lastly, cost.

The very low available or actual pressures obtained necessitate large cylinders and pistons, which, with dry hot air, require good lubrication, and cause a large percentage of friction. Difficulties occur with the pistons and rings from the heat ; the packings also give considerable trouble, and the furnace repairs become vexatious and expensive. The greatest drawback to their more general use is, of course, the great size and cost of a hot air engine as compared with its effective power ; on the other hand they are convenient because they give little trouble in working, there is no steam, no boiler, and no risk of explosion, and they can be started in a few minutes.

In renewing the cylinder bottoms, hard cast iron (white or mottled pig) should be used. Soft grey pig burns rapidly. If there is any machine work, however, to be done on them sufficient grey iron must be employed in the mixture to leave it soft enough to cut ; say equal parts of white and of No. 1 Scotch.

Section IV.—*WATER MOTORS.*

CHAPTER XVI.

WATER WHEELS AND TURBINES.

THE uses and applications of water power are necessarily restricted. There are comparatively few positions where the power is available, and the work must be brought to the motor, which is seldom convenient and economical; besides which, the power fluctuates frequently as to quantity, and sometimes has to be supplemented by steam. The types of motors in use comprise water wheels of all forms, turbines, rotary motors, water-pressure engines and hydraulic rams. For pumps and pumping engines see Chapter VI.

Water wheels are of several forms, each best suited to particular circumstances of the water supply. In overshot wheels the water enters the wheel at the top. In undershot wheels it runs under the wheel, filling the lower buckets as it passes. In breast wheels the water enters about half way up the wheel. In horizontal and diagonal wheels the buckets are on the upper face, and receive the water from a shoot at a tangent to the wheel. Flutter wheels or high speed wheels are of comparatively small diameter, with a high fall of water which strikes the wheel just above the centre line. Internal wheels have internal buckets, the water entering them as high as possible. Scoop wheels are breast wheels driven backwards to raise water, and are therefore, properly speaking, pumps or water raisers.

The construction of all these forms of wheels is practically similar. A shaft—often of wood, sometimes of cast iron

seldom of wrought iron—runs in two bearings at opposite sides of the wheel pit or race. On it are keyed or "staked" two or three centre-pieces cast with sockets to receive wood arms, which are socketed at their outer ends in cast iron segments, forming the outer rings or shrouding, with flanges cast on to receive the ends of the bucket boards. These are generally of elm or oak, but sometimes of sheet iron. In the best designs these are ventilated as Figs. 222 and 223, to allow the air to escape rapidly as the water enters with a rush, as in many cicumstances they do not otherwise fill properly. An overshot or breast wheel should not run in the tail water, as it creates some resistance, but be raised high enough to be clear of it even in flood seasons. Undershot wheels should have very little clearance between the wheel and the race, so that the water is nearly all driven into the buckets. Water wheels give from 60 to 75 per cent. efficiency, and the H.P. can easily be calculated by multiplying the weight of water falling into the race per minute by the actual height of fall and divide by 33,000. From 60 to 75 per cent. of this result may be obtained in practice.

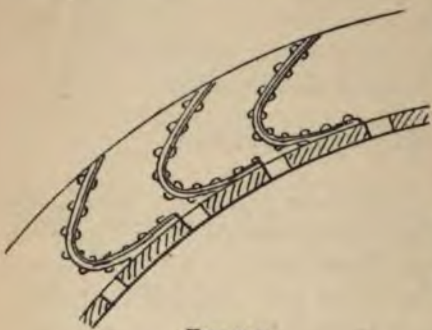


FIG. 222.

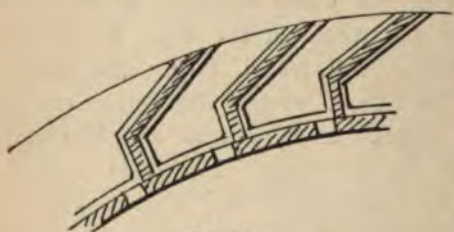


FIG. 223.

Wrought iron should be avoided in the construction of water wheels as it corrodes very rapidly; all bolts used should be galvanised, and, as far as possible, the floats or buckets constructed so as to be easily renewed without disturbing the shrouding.

For a low fall a breast wheel will give better results than a small diameter overshot wheel, and for a high fall an overshot wheel of large diameter is employed, but is now generally displaced by the turbine. Besides the cost of building a wheel, considerable expense is incurred in constructing flume, wheel pit, sluices, &c., generally of masonry.

Variable speed and power can easily be given to a water wheel by varying the water supply by a sluice or by the valve shown in Fig. 224.

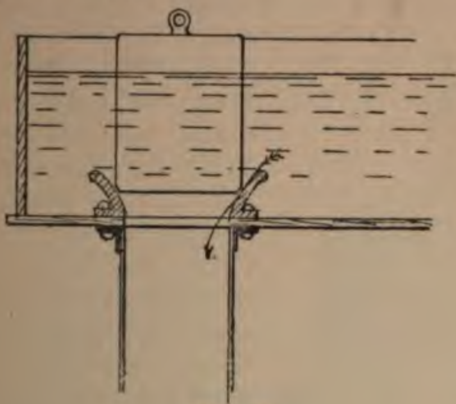


FIG. 224.

Turbines are enclosed fans or centrifugal wheels which revolve between fixed abutment blades attached to the case all round the wheel. There are several varieties, each having its special advantages, either for high or moderate falls and great or small volumes of water. They run at high speeds, nearly all the varieties work horizontally, they occupy a very small space for the power developed, they give a good percentage of useful effect, sometimes amounting to 80 per cent., which, considering that the motion is not positive but centrifugal, or due to reaction pressure only, must be considered to be remarkably good. They are thus displacing water wheels to a great extent; the difficulties in connection with them arise from their high speed, vertical running shaft and its footstep bearing, and the difficulty of regulating their speed; some of the latest designs are worked horizontally

however. The high speed is, of course, reduced to the driven shafting by gearing. The vertical shaft is provided with a special footstep bearing, sometimes of lignum vitæ, with means of adjustment. The speed is regulated in some forms of turbines by varying the angle of the vanes, somewhat in the same way that the sails of a windmill are made variable. This adjustment is, of course, made while running, sometimes it is applied to the fixed vanes of the case only. The various types of turbine include different cycles of flow for the water. Fourneyron's and Boyden's turbines have the fixed vanes in the centre and the wheel vanes in a zone around them, the water entering the centre and flowing outwards. The Jonval turbine has a downward flow, the fixed guide vanes being above the wheel. Swain's turbine has inward and downward flow, the water entering the wheel by passing horizontally through the fixed vanes and flowing downwards around the footstep bearing by a bell-mouth opening. Schiele's turbine is of the inward flow type, the water entering a tapering spiral case, like that of a blast fan, laid horizontally, forming a vortex; it passes through a ring or zone of fixed vanes into the wheel, and is discharged both upwards and downwards around its centre. The Leffel turbine is of the inward and downward flow type; the wheel has two eccentric sets of vanes, the outer one discharging vertically downwards, the inner one discharging into the centre downwards, these are supplied by a horizontal flow all round through a zone of fixed vanes. There are other varieties which are modifications of these. The Victor turbine wheel has two sets of vanes, by which it gets a double impulse from the water, as

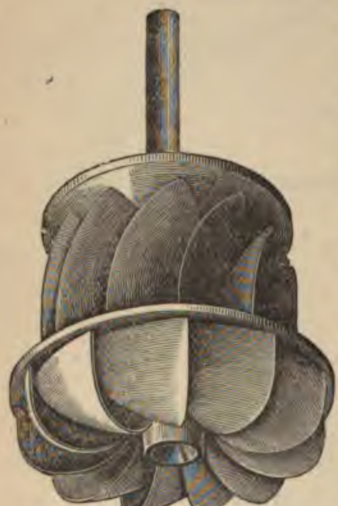
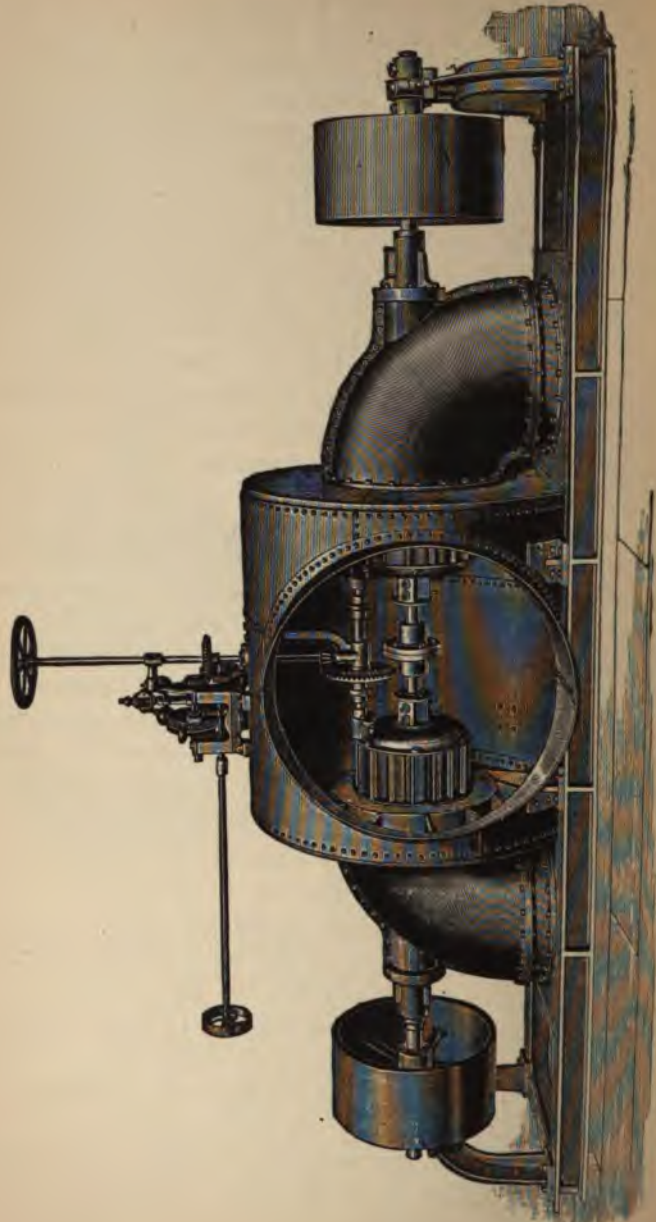


FIG. 225.

shown detached from the case in Fig. 225; it is of the inward and downward flow type, and is fixed either vertically or horizontally, but has special adaptability to the horizontal arrangement, as in Fig. 226, which shows a pair coupled to one shaft and fixed inside a wrought-iron flume. This horizontal construction greatly simplifies the shaft arrangements for driving mills, or dynamos, and, in fact, nearly every kind of drive is most easily worked from a horizontally running motor. An automatic governing device is attached to these turbines, driven by belt from the shaft and arranged to actuate the chute or cylindrical gate to regulate the quantity and direction of flow of the water into the wheel and thus vary the speed. A very high efficiency is claimed for this turbine. The Pelton wheel is a free impulse wheel on a horizontal axle and is extensively used in America. It has the advantage of a horizontal shaft, which is easier to drive from than a vertical one, and it is adapted for very high falls. The Girard turbines are also used with very high falls, and claim an efficiency of as much as 85 per cent. Two or more turbines are sometimes fixed to drive one shaft, either of which can be stopped if not needed. There is practically no limit to the head of water that can be employed; as much as 350 feet has been used, and low pressure turbines will run with a head of 1 foot only. The H.P. is found by multiplying the head in feet by the weight of water per minute and dividing by 33,000 = theoretical H.P. The actual power will be from 60 to 80 per cent. of this. It is difficult to give any certain information as to their comparative performances, as the working conditions vary so much. Jonval's is generally considered the most effective, and its form is easily varied to suit any fall, but there is not a large difference between the best and the worst; whilst some are adapted to be most effective for high falls, others are best for low falls and large volumes. The reader is referred to Weisbach's 'Hydraulic Motors' for further details.

The fixing, however, is a much simpler matter than that of a water wheel. Either a strong wood frame or cast-iron cross-bearers are fixed in the masonry, leaving sufficient room



ft.	in.																
3	3⅜	Horse power	·21	·48	·88	1·33	1·99	2·66	3·8	5·2	7·2	8·6	10·6	12 8	15·2	19·6	25·8
		Cubic feet per minute ..	45	101	187	282	403	564	806	1094	1522	1814	2250	2692	3252	4151	5488
		Revolutions	295	197	147	118	98	118	98	84	78	65	59	53	49	42	37
6	7	Horse power	·6	1·3	2·5	3·7	5·4	7·4	10·8	14·8	19·4	24·4	30·2	36·4	43·8	56·0	72·8
		Cubic feet per minute ..	63	144	267	401	576	802	1152	1570	2050	2596	3202	3262	4648	5932	7700
		Revolutions	420	280	210	168	140	168	140	120	105	93	84	76	70	60	52
10	0	Horse power	1·1	2·5	4·5	7·1	10·2	14·2	20·4	27·8	36·2	45·8	56·6	68·4	83·6	105·0	138·6
		Cubic feet per minute ..	69	180	319	501	720	1001	1440	1962	2560	3242	4004	4838	5760	7416	9784
		Revolutions	525	350	251	210	175	210	175	150	131	116	105	95	87	75	66
13	2	Horse power	1 7	3·5	7·2	10·7	18·9	21·4	31·0	42·2	55·4	63·4	86·4	104·6	125·5	160·4	210·0
		Cubic feet per minute ..	60	206	381	568	823	1136	1646	2234	2930	3714	4576	5544	6638	84·78	11128
		Revolutions	600	400	300	240	200	240	200	171	150	133	120	109	100	86	75
16	5	Horse power	2·4	5·4	10·1	15·2	21·8	30·4	43·6	55·2	77·8	99·6	121·4	147·6	175·4	224·0	294·0
		Cubic feet per minute ..	101	231	429	642	925	1284	1850	2342	3302	4184	5148	6256	7416	9496	12432
		Revolutions	575	450	337	270	225	270	225	179	169	150	135	123	112	96	84
19	8	Horse power	3·1	7·1	13·2	19·9	28·5	39·8	57·0	79·8	101·8	128·8	158·8	193·0	229·4	294·0	386·4
		Cubic feet per minute ..	111	252	466	705	1008	1410	2016	2746	3594	4552	5608	6846	9296	13782	13650
		Revolutions	735	490	367	295	245	295	245	210	184	163	147	134	122	105	92
23	0	Horse power	4·0	9·0	16·8	25·1	36·0	50·2	72·0	98·0	125·2	163·2	200·4	243·2	289·4	369·2	485·0
		Cubic feet per minute ..	119	273	507	759	1091	1518	2182	2966	3842	4940	6064	7388	8758	11164	14668
		Revolutions	795	530	398	318	265	318	265	227	199	177	159	145	132	113	99
26	3	Horse power	4·8	11·0	20·4	30·8	44·0	61·6	88·0	118·4	156·4	199·2	244·8	297·6	356·0	452·0	593·6
		Cubic feet per minute ..	128	292	542	812	1165	1624	2330	3138	4138	5276	6484	7854	9436	11982	15722
		Revolutions	850	567	425	340	283	340	283	243	212	189	170	155	142	121	106
29	6	Horse power	5·8	13·1	24·3	36·5	52·4	73·0	104·8	141·0	186·8	236·0	291·6	352·0	423·5	537·9	705·6
		Cubic feet per minute ..	136	309	572	860	1234	1720	2468	3320	4396	5580	6864	8298	9958	15718	16608
		Revolutions	900	600	450	360	300	360	300	257	225	200	180	163	150	128	112
32	10	Horse power	6·7	15·3	28·5	42·8	61·5	85·6	123·0	167·2	218·4	278·0	342·0	415·2	495·0	635·0	833·0
		Cubic feet per minute ..	143	326	606	908	1305	1816	2610	3544	4630	5890	7242	7946	10478	13430	17654
		Revolutions	950	633	475	380	317	380	317	271	237	211	190	173	158	136	119
36	1	Horse power	7·8	17·8	33·2	49·6	77·1	99·2	154·2	194·2	253·6	321·6	396·0	480·4	575·6	733·2	962·4
		Cubic feet per minute ..	151	342	637	953	1370	1906	2740	3740	4886	6198	7648	9252	11082	14126	18538
		Revolutions	1000	666	500	400	333	400	333	286	250	222	200	182	167	143	125
39	5	Horse power	9·0	20·4	39·8	56·7	81·6	113·4	163·2	222·2	289·8	368·4	453·6	550·0	661·8	840·0	1100·4
		Cubic feet per minute ..	158	360	667	1001	1440	2002	2880	3924	511·6	6494	8024	9718	11676	14832	19432
		Revolutions	1050	700	525	420	350	420	350	300	262	233	210	191	176	150	131

TABLE FOR SMALL TURBINES, WORKING UNDER HIGH FALLS.

Head of Water in feet and inches.	Horse Power.	Cubic feet of water used per minute.	Revolutions.	Horse Power.	Cubic feet of water used per minute.	Revolutions.	Horse Power.	Cubic feet of water used per minute.	Revolutions.
ft. in.									
42 8	10·1	164	1081	23·4	381	721	42·4	686	540
45 11	11·2	170	1122	26·1	396	748	47·0	712	561
49 3	12·5	176	1161	29·0	410	774	52·2	738	580
52 6	13·8	182	1200	32·0	424	800	57·6	763	600
55 9	15·1	188	1237	35·1	438	825	63·0	785	618
59 7	16·4	193	1273	38·2	450	848	68·5	807	636
62 4	17·8	198	1308	41·4	362	872	74·5	830	654
65 7	19·2	204	1342	44·7	473	894	80·6	852	671
68 11	20·3	209	1375	48·1	485	916	86·4	872	687
72 2	22·0	214	1407	51·7	496	938	92·9	893	703
75 6	23·6	218	1439	55·3	507	959	99·4	914	719
78 9	25·2	223	1470	58·8	519	980	105·8	934	735
82 0	26·9	227	1500	62·6	530	1000	112·7	952	750
85 4	28·6	232	1530	66·4	540	1020	119·6	978	765
88 7	30·2	237	1559	70·2	550	1039	126·5	992	779
91 10	31·9	241	1587	74·2	560	1058	133·6	1008	793
95 2	33·6	245	1615	78·1	570	1077	140·7	1026	807
98 5	35·3	249	1643	82·1	579	1095	147·8	1044	821

In calculating the above tables, the efficiency is taken at 75 per cent. It will be observed that the quantity of water given is greater than that which is found in many tables of American origin, but no turbine, however good, can be depended on to give the power in the tables with either less water or a less fall.

in the wheel pit to get round it easily. The water is led by a pipe to the wheel case, usually of cast iron, but frequently of wrought iron and riveted. The upright shaft drives a horizontal one by bevel gear, proportioned so as to reduce the speed of the wheel to that required for the main shaft. Gratings must be fixed to prevent floating obstructions from getting into the wheel, and the bearings of the vertical shaft are lubricated through pipes led from any convenient point.

The casualties are generally broken vanes or buckets; in the best designed wheels these are easy to replace. There

is little else about them liable to injury, except in those that have adjustable fixed vanes, with outside arms and gear for moving them.

In small turbines the internal parts are of brass or other non-corrodible metal, and though greater in first cost, save much in repairs.

As these motors run at high speeds, the bearings require maintaining in good order. The lubrication also is important, though lignum vitæ bearings are said to run without other lubricant than the water.

The tables, pp. 231, 232, give the H.P., head and quantity of water, and speed of turbines, under various conditions.

CHAPTER XVII.

WATER PRESSURE MOTORS AND ROTARY MOTORS.

Water Pressure Engines comprise engines—other than rotary motors—in which water pressure is used to reciprocate a piston in a cylinder, as in a steam engine; the work done being usually either driving a shaft, a pump, or a hoisting apparatus. They are used in mines as winding or hauling engines, also to pump out dips and workings, and to drive ventilating fans, rock cutting machines, &c.; in these cases they generally obtain their water supply from the rising main of the mine pumping engine, but are sometimes driven by a surface supply taken down the mine in a separate pipe, the exhaust water going with the drainage to the "sump," from which it is pumped to the surface by the main pump. In these cases the pressure is generally high, from 100 to 400 lbs. per square inch, so that a small motor cylinder will give a considerable effort. But as the water is non-elastic and no expansion is possible, it is used at full pressure throughout the stroke, and the cushioning at each end

becomes a difficult matter. The valve is a slide or piston valve and is generally moved by tappets, or by an auxiliary valve which reverses it at each end of the stroke. To prevent this valve sticking when at half its stroke, at which point it cuts off the water supply and stops the piston movement, some form of momentum or gravity attachment is used to continue the movement of the valve until it is fully reversed.

With an engine having a rotary motion from the piston, as in the steam engine, the ordinary eccentric and rod will give the required movement, the slide valve having no lap, in fact, it is made slightly too short to cover the supply ports, so that water is admitted momentarily to both ends of the cylinder (Fig. 227); the momentum of the engine then carries the crank over the dead centre; but it is better to couple two or three engines to one crank shaft so as to avoid dead centres altogether. The ports are all of one size; there is no lead to the valve and no cushioning.

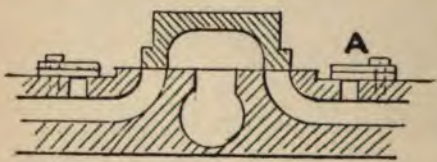


FIG. 227.

This necessitates a slow piston speed, in fact high speed is impossible, from the fact that the water will not travel fast enough. Air vessels on the valve box are necessary to cushion the current of pressure water, and should be of considerable size and strength when the pressure is high.

When a tappet gear is used in engines without a crank motion, a small relief valve A must be fixed to each supply port to allow of the escape of any water confined between the piston and cover back into the valve box, and thus prevent thumping at the ends of the stroke; a small spring piston in each cover will effect the same object (see p. 105).

The favourite, and perhaps, the most satisfactory form of water pressure engine is the three-cylinder single acting engine; there are several forms of it in use. The three cylinders are coupled to a three-throw crank shaft, or, as in Brotherhood's engine, the three cylinders are set in a circle at

120° apart and coupled to one crank; the oscillation of the cylinders on trunnions is used to operate the ports, which are either in the base of the cylinder or in fixed segmental boxes at the sides, and the amount of oscillation gives the travel of the valve or its equivalent, that is, three times the width of one port. The port faces are kept together by screw or spring adjustments. With this plan all packings are external, there is a continuous rotary effort without fly-wheel, the working parts are reduced to the least possible number, and are simple and easy of access. These engines have faults and are liable to stoppages and breakdowns due to the use of water as a motor fluid, which increase with the pressure; grit chips, &c., cause stoppages by blocking the slide valve or the auxiliary valve. Thumping is set up by any inaccuracy of adjustment of the slide valve. Piston and slide valves, which are moved by the pressure of the water, are liable to stick or to get so loose that the water passes them without moving them, or they get set on the half stroke, closing all the ports. Leathers are used as packings for all rods and pistons, and of course wear out rapidly in cast-iron cylinders, or with corroded steel or iron rods. The valves and port faces are always of brass or bronze.

For organ blowing they are much used, but are best, or at least most reliable, when of the three-cylinder type. They are of brass throughout or brass-lined, and if carefully adjusted at the valves will not thump, a matter of great importance for this service.

The working parts of these engines, crank shafts, centres, bearings, trunnions, &c., are similar to those in steam engines, but sometimes liable to greater corrosion from water leakages, wet situation, &c. In such cases phosphor bronze should be substituted for rods and centres, cross-heads and like working parts.

Hydraulic rams are, strictly speaking, automatic pumping machines which utilise a low fall and large volume of water to raise a smaller quantity to a greater height; the two supplies are usually from the same source, but there is one form in use that will use a low fall of dirty water to raise

another supply of clear water for domestic purposes. Though a very old invention, it is still very largely used for this particular kind of service. The working parts are merely two valves, one opening inwards and downwards is the discharge valve, the other opening upwards into an air vessel, from the base of which the delivery pipe is taken. The proportionate areas of these valves depend upon the heads of supply and delivery. Rams are easily fixed at the foot of any fall of water of not less than 3 feet in height. The supply pipe is fixed in a sloping direction and the delivery pipe led as direct as possible to its destination. The useful effect is shown in the following table, and the size and capacity is dependent on that of the supply pipe and available head. They work automatically without attention or lubrication; the only parts needing repairs are the valves, which beat hard, especially the delivery, and require the seatings and faces refitted occasionally.

EFFICIENCY OF HYDRAULIC RAMS.

Lift ÷ Fall	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25
Efficiency per cent.	75	72	68	62	57	53	48	43	38	35	32	28	23	20	17	15	12	10

Rotary Motors. Pumps and Meters.—The problem of a reliable rotary motor having a positive pressure abutment, expansive action and capable of being kept steam tight is still unsettled, though a vast amount of energy has been spent in its development. A few useful and practicable forms have been produced, and have found particular applications. The idea of direct rotary without reciprocating motion is certainly tempting to inventors and may some day be fully realised.

Rotary motors are, generally speaking, applicable equally as motors, meters or pumps, the latter term including blowers (see p. 210). Several that were originally designed as motors have found better applications as pumps or blowers.

They may be divided into two classes, single cylinder, and double cylinder motors. In the former, some form of piston —oval, cam-shaped or eccentric—revolves, and moves one or

more abutment slides in and out of recesses as it revolves. In the latter, two pistons revolve in opposite directions, overlapping and gearing with one another in different ways, and there seems to be no end to the possible combinations of these two types. There is another type which, however, has not made much progress yet, viz. the steam turbine, a form of reaction wheel in which expanding steam is the motor fluid.

The paramount difficulty with all of them is the packing of working joints and faces. It is extremely difficult to make them fluid tight, and still more difficult to keep them so. In a cylinder and piston circular spring rings are an easy and reliable joint; but with a square or rectangular piston having corners it is by no means easy to provide for expansion every way; besides which, in nearly all cases the packing joint of the moving piston is not always in contact with the cylinder surface, but crosses two or more such surfaces in a revolution, and therefore springs out and in. Under steam or compressed air the losses would be great under these conditions, and the wear and tear equally unsatisfactory. Such motors as have a market have depended chiefly on good workmanship to minimise this fault, and there is a good opening for a really satisfactory rotary motor for steam or water power.

As pumps, however, they have found more useful and satisfactory applications; the fluids (water, oil, &c.) help to keep the working joints tight; they are seldom used for high lifts or deep suction, for which services they are unsuitable, but for all ordinary pumping uses in houses and factories they give satisfaction, and are simple and handy. These are of the double piston type. As blowers or air pumps they are still more largely used (see p. 210).

As meters, rotary devices answer fairly well, at least for water. Gas pressures are not sufficient to drive them without considerable leakage at the piston packings. The whole construction and packing must be as near as possible frictionless.

The repairs and renewals to all rotary motor devices are chiefly confined to the packings and the centre stuffing box bearings. These latter tend to wear to one side and cause

the piston to run out of truth. In some of them this does not occur, because the piston by fitting the bore converts it into a bearing. It is scarcely possible to provide adjustable stuffing box bearings, and this being so, the best alternative is to considerably increase their length, which, without adding to the friction, greatly adds to the wearing surface and life of the bearing. For water, cup leather packings are the best, and are most generally used, the friction being much less than with ordinary yarn packing pressed tightly into a box, and for meters freedom from friction is essential, especially with low pressures. With very high pressures, such as that of 700 lbs. per square inch, as used by the London Hydraulic Power Company and others, meters are not reliable, and the water is measured, after passing through the hydraulic machinery, at ordinary pressures. A piston and cylinder having a fixed length of stroke is one of the best forms of water meters: a rack is attached to the piston, and by revolving a spur pinion actuates the inlet and outlet valves, and drives the counter. Other piston meters are simply complete engines with crank shafts and valve gear. The turbine has been used to measure water, but the measurement is not a positive one, the error varying with the speed and pressure.

A meter should always give a positive measurement, and should be graduated by actual test quantities of water, either by altering the counter, or altering the stroke to deliver at the speed indicated by the counter if the latter has no adjustment. New meters are tested and stamped officially, but few are reliable for any length of time, the error being generally in favour of the consumer. The power they utilise is a small fraction of the actual pressure, so that there is—when the meter is working—a slight loss of pressure on the delivery side. They should be fixed in such a position as not to trap the air that all waters contain more or less, so that a low position with the pipes dipping to the meter is best. The water companies have their own rules as to this, and sizes of pipes, positions of valves, &c., and from them all such information must be obtained in every case, so that their regulations may be conformed to.

SECTION V.—*TRANSMISSION OF POWER.*

CHAPTER XVIII.

SHAFTING.

POWER is conveyed from the various types of motors by the following means :—

1. Shafting with pulleys, bearings, &c.
2. Toothed gearing.
3. Belts, ropes, chains.
4. Pipes.
5. Rods and guides.

Of these methods, the first three are the most common, and generally the most convenient. A line of shafting is fixed overhead in the building, extending from the motor to the furthest position where power will be required, and the machines are arranged below it, as far as possible in parallel lines, the heaviest nearest the motor and the lightest the farthest from it. If the line of shafting is of considerable length, it is best and most economical to fix the motor in or about the centre of its length, as by this means a lighter section of shaft will convey the power.

Shafts at right angles should be avoided, if possible, as they require bevel gear to drive them. Ordinary iron wheels in these circumstances are very noisy. Mortise gear is sometimes used, and is quieter than iron wheels. Double helical gear is also quieter, if well made and well geared.

There is also a type of patent angle coupling made by T. R. Almond of New York, which is perfectly quiet, and gives a regular and even drive in place of bevel gear.

Where bevel gear is used on a long line shaft it is necessary to apply collars to the shafts to prevent end movement which would cause them to gear badly or run out of gear; very strong hangers are also required.

The setting out of a machine shop or factory and arrangement of shafting is often a matter of "rule of thumb," whereas it ought to be well thought out and the entire arrangement planned on paper to scale, the speed and position of every driving pulley set out, and the shafts arranged to run at a speed intermediate between the average of the machines and that of the engine. The pulleys, bearings, hangers and couplings can then be set out, their diameters and widths calculated, and the pulleys and other gear ordered with a reasonable certainty of their being satisfactory.

Line shafting can be tapered down in diameter from the engine to the extreme end if cost is important, but it often leads to inconvenience if a machine or pulley requires shifting to another place, the pulley having to be bushed to fit the smaller shaft, or bored out if a larger eye is required. It is a moot question whether the inconvenience of having several sizes of shafts, bearings, hangers, &c., is not greater than the slight loss of power from running a heavier shaft than necessary where a parallel one is employed throughout. Very long line shafts are undesirable. They spring a good deal from their great length, and must be made very heavy in section to stand the torsional strains, and consume a good deal of power in consequence. Very few manufacturers take indicator diagrams with the engine and shafting running empty to show how much coal is consumed by the shafting; but such information would often be instructive and surprising. It must be remembered that any saving in the power lost by shaft, gearing and belt friction is an annuity, being a constant percentage off the coal bill. For this reason well-designed shafting, well fixed, is an important matter in view of economy in running and repairs.

Vertical shafting is rarely satisfactory. The footstep bearings give trouble, they run very heavily also; belts from them being horizontal, require wide-flanged pulleys and run heavily;

the edges stretch and crack and lead to frequent renewals. To carry power to upper floors, therefore, belts are far preferable, but should not be run vertically (as A, Fig. 228), as they need then to be kept unusually tight, which causes stretching and excessive friction. As much slope as possible should, in fact, be given to *all* belts, they then hang partly on both pulleys, can be run with more slack, and grip both pulleys best when driven in the direction shown.

Every machine must be fixed with its driving shaft parallel to the line shaft. If it has a counter-shaft and speed pulleys, these should be so placed as to give a fair length to both belts (as Fig. 229), and so that the machine belt is not vertical. Vertical driving belts slacken, of course, at the lower pulley

FIG. 228.

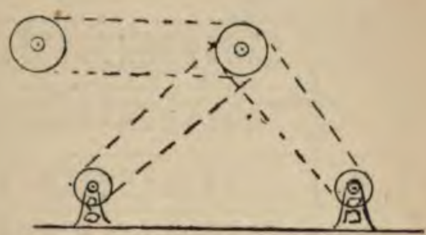


FIG. 229.

and loose their bite, so that the machine man always pulls them up very tight, which shortens their life and causes friction.

Steel Line Shafts.—The following table gives the powers that steel line shafts will transmit at speeds varying from 50 to 500 revolutions per minute, and by simple application of the decimal point, may be made to answer for speeds ranging from 5 to 5000 revolutions per minute.

The powers given are well within the safe limits of line shafting, and will cause a torsion of less than one degree per foot run. If the shafts are used as prime movers, they should not be required to transmit more than 70 per cent. of the power given in the table.

Wrought-iron Line Shafts.—These may be taken as capable of transmitting 70 per cent. of the power of a steel

POWER THAT STEEL SHAFTING WILL TRANSMIT AT VARIOUS SPEEDS.

Revolutions per minute.	Diameter of Shafts.																		
	1½	1¾	2	2¼	2½	2¾	3	3½	4	4½	5	5½	6	6½	7	7½	8	9	10
	Horse-powers they will transmit.																		
50	3·3	5·3	8·0	10·9	15·6	20·8	27	43	64	91	125	166	216	275	343	422	512	729	1000
60	4·0	6·4	9·6	13·1	18·8	25·0	32	51	77	109	150	200	259	330	412	506	614	875	1200
70	4·7	7·5	11·2	15·2	21·9	29·1	38	60	89	128	175	233	302	385	480	591	717	1021	1400
80	5·4	8·5	12·8	17·4	25·0	33·3	43	69	102	146	200	266	346	439	549	675	819	1166	1600
90	6 0	9·6	14·4	19·6	28·1	37·4	49	77	115	164	225	299	389	494	617	759	922	1312	1800
100	6·7	10·7	16·0	21·8	31·2	41·6	54	86	128	182	250	333	432	549	686	844	1024	1458	2000
110	7·4	11·8	17·6	23·9	34·4	45·8	59	94	141	200	275	366	475	604	755	928	1126	1604	2200
120	8·1	12·9	19·2	26·1	37·5	49·9	65	103	154	219	300	399	518	659	823	1012	1229	1750	2400
130	8·7	13·9	20·8	28·3	40·6	54·1	70	111	166	237	325	433	562	714	892	1097	1331	1895	2600
140	9·4	15·0	22·4	30·5	43·8	58·2	76	120	179	255	350	466	605	769	960	1181	1434	2041	2800
150	10·1	16·1	24·0	32·6	46·9	62·4	81	129	192	273	375	499	648	824	1029	1265	1536	2187	3000
160	10·8	17·1	25·6	34·8	50·0	66·5	86	137	205	292	400	532	691	879	1097	1350	1638	2333	3200
170	11·5	18·2	27·2	37·0	53·1	70·7	92	146	218	310	425	566	734	934	1166	1434	1741	2479	3400
180	12·2	19·3	28·8	39·2	56·3	74·9	97	154	230	328	450	599	778	989	1235	1519	1843	2624	3600
190	12·8	20·4	30·4	41·3	59·4	79·0	103	163	243	346	475	632	821	1044	1303	1603	1945	2770	3800
200	13·5	21·4	32·0	43·5	62·5	83·2	108	172	256	365	500	665	864	1099	1372	1687	2048	2916	4000
225	15·2	24·1	36·6	49·0	70·3	93·6	122	193	288	410	563	749	972	1236	1543	1898	2304	3280	4500
250	16·9	26·8	40·0	54·4	78·1	104·0	135	214	320	456	625	832	1080	1373	1715	2109	2560	3645	5000
275	18·6	29·5	44·0	59·8	85·9	114·4	149	236	352	501	688	915	1188	1510	1886	2320	2816	4009	5500
300	20·3	32·2	48·0	65·3	93·7	124·8	162	257	384	547	750	998	1296	1648	2058	2531	3072	4374	6000
325	21·9	34·8	52·0	70·7	101·6	135·2	176	279	416	592	813	1081	1404	1785	2229	2742	3328	4739	6500
350	23·6	37·5	56·0	76·2	109·4	145·6	189	300	448	638	875	1165	1512	1922	2401	2953	3584	5103	7000
375	25·3	40·2	60·0	81·6	117·2	156·0	203	322	480	683	938	1248	1620	2060	2572	3164	3840	5468	7500
400	27·0	42·9	64·0	87·0	125·0	166·4	216	343	512	729	1000	1331	1728	2197	2744	3374	4096	5832	8000
425	28·7	45·6	68·0	92·5	132·8	176·8	230	364	544	775	1063	1414	1836	2334	2915	3585	4352	6197	8500
450	30·4	48·2	72·0	97·9	140·6	187·2	243	386	576	820	1125	1497	1944	2472	3087	3796	4608	6562	9000
475	32·1	50·9	71·0	103·4	148·4	197·6	257	407	603	866	1188	1580	2052	2609	3258	4007	4864	6926	9500

shaft the same size. In all cases the shaft should be well supported with bearings at suitable intervals. The following table will serve as an approximate guide in fixing on the distance of the bearings apart :—

TABLE GIVING CENTRES OF BEARINGS FOR LINE SHAFTS CARRYING A FAIR PROPORTION OF PULLEYS.

Diameter of Shaft in inches.	1½	1¾	2	2¼	2½	2¾	3	3½	4	4½
Centres of Bearings apart.	ft. in. 7 0	ft. in. 7 6	ft. in. 8 0	ft. in. 8 6	ft. in. 9 0	ft. in. 9 6	ft. in. 10 0	ft. in. 11 0	ft. in. 12 0	ft. in. 13 0

5	5½	6	6½	7	7½	8	9	10	Diameter of Shaft in inches.
ft. in. 13 6	ft. in. 14 0	ft. in. 15 0	ft. in. 15 6	ft. in. 16 0	ft. in. 17 0	ft. in. 18 0	ft. in. 19 0	ft. in. 20 0	Centres of Bearings apart.

Shafts without Pulleys.—If shafts are simply used for the transmission of power, and do not carry any pulleys, the bearings may be spaced 50 per cent. further apart than in the table given above. On the other hand, extra bearings should be placed near pulleys which transmit much power.

Bearings, Hangers and Couplings.—Self-adjusting bearings are now generally used, brasses are not needed, as they are made very long, and the shafts being usually of mild steel turned parallel to gauge throughout, no necks or journals are used, and they run as well in cast iron as in brass. Any wobbling is very objectionable, as it causes wear and unsteady driving, besides being unsightly and unworkmanlike. One end only of each shaft must be collared, to prevent end movement ; this may be effected by a pair of loose collars fixed one on each side of a bearing.

Double brassed bearings are sometimes used, but single brasses are sufficient for general purposes, as there is no wear on the top brass ; the caps should be bolted down hard, leaving a slight play in the brasses without looseness. Wall boxes

should be built in cement and not eclipsed, as is often done by large pulleys, so that their bearings cannot be reached.

Wrought-iron hangers are the safest, undoubtedly, but are not handsome. Double hangers of both wrought and cast iron have the disadvantage that the shaft cannot readily be lifted out, but if split pulleys are used this matters but little. If side hangers are used they should have a good fixing base, and the vertical centre line of the shaft should be at about the centre of the base, to equalise the strain on the fixing bolts.

Lining up and Levelling.—A shaft must be both straight and level to run at its best. A fine strong line should be strained tight in the centre of the bearings and levelled, and all the hangers fixed correctly to it. The couplings are best near to a hanger or bearing, but this is not essential. The distance apart of the hangers is more important, and varies with the diameter of the shaft and the distribution of the belts. If these are evenly divided, that is, as many pulling one way as those that pull the opposite way, longer intervals may be used than when they all pull the same way. In the first case, an interval of from 50 to 60 diameters may be used, and in the latter case, from 40 to 50 diameters, otherwise the figures in the table, p. 243, may be adhered to.

Planished black shafting is rolled now both in iron and steel, with considerable accuracy and finish, and may be safely used for plain shafting for all ordinary purposes. It is cheaper than turned shafting, and stronger for the same section, as the skin of the bars has been consolidated by the peculiar rolling, while the skin of ordinary turned shafting has been cut away, leaving the unconsolidated metal only remaining.

Couplings of the compression type are now much used in place of keyed couplings; they require no bolts, so that there s nothing projecting to catch a man's clothes, or a belt. If flanged couplings are used, the bolts should be small and sunk in recesses, so that the heads and nuts do not project.

Flanged couplings require facing after being keyed up to the shaft ends, otherwise the key will be found in many cases

to have thrown the coupling a little out of truth, the error being many times magnified by the length of the shaft. Keys also should be plain, without gib heads, to prevent catching a workman's clothes. For all light pulleys hollow or saddle keys will give sufficient grip; heavier pulleys and toothed wheels should have sunk keys. The compression grip plan is being introduced also for pulleys, to avoid keys and key beds, and appears to be generally satisfactory; but for large pulleys and heavy gear, nothing less than a well sunk key is reliable, and in fact two keys at right angles to one another are preferable (see Key Fitting, p. 74).

Set screws are sometimes used and will answer for light drives, but the heads projecting from the boss are objectionable as possible sources of accident.

Pulleys.—Formerly almost solely made of cast iron, are now made frequently of wrought iron throughout, or with wrought-iron rim and arms and a cast boss. This makes a much lighter pulley, and it is practically unbreakable, but not quite so rigid as cast iron, and in some cases the rim is not so true, as they are not turned. The rim is riveted at the joint, or if the pulley is split at the boss so as to be sprung open enough to slip over the shaft, then the lap joint of the rim is bolted together.

Wood pulleys are now becoming largely used, especially in America, and give much satisfaction; they are built up of ash, hickory, teak or sycamore, the segments glued and riveted together, and the whole turned true; they hold the belt well, are light and stiff, and being always split, can be put on the shaft anywhere and bolted up without keys. The system of *always* employing *split* pulleys is much in vogue; the necessity for moving them frequently, when changes of machines or of speeds are made, makes the plan a very convenient one. Those on the line shaft should always be of ample width, to allow for the travel of the belt, and also for its running a little out of line, as it often will. They should also be keyed up so as to run true; a wobbling pulley is a great eyesore in a machine room. Very large and very small pulleys are best avoided, and the speeds required obtained by an intermediate pair

on a countershaft; better running is obtained this way, and the sizes of pulleys become more reasonable, with better grip for the belts.

Bent shafts are straightened by putting them between the centres of a heavy lathe, the bent spots are marked by turning the shaft round, and a strong lever used to take them out. Hammering them in V blocks on a heavy bed or surface table is not so good, as it causes "kinks," which are much more troublesome than bends, but this plan must sometimes be resorted to. In these cases the shaft should be black heated: moderate blows will then do what is required. After straightening, the couplings—if any—will need refacing if flanged.

Broken pulleys may be repaired as shown on p. 252.

Flanged couplings should always be faced up on their shafts after keying up.

Necks and collared journals should always be avoided in line shafts, they are in the way in getting pulleys on and off, and the journals prevent expansion of the shaft due to changes of temperature.

CHAPTER XIX.

TOOTHED GEARING.

TOOTHED gearing is used wherever *positive* relative motion is required; belts slip or creep, but in some cases chain gear is a good and useful substitute for toothed gear (see Chains, p. 254). The form and setting out of teeth have been so much dwelt on by writers, that we do not propose to deal with it here, but refer the reader to the work named below for full information.*

Cast iron is almost invariably used, except for wheels subject to great wear or strains, and for the teeth of mortise wheels. Steel castings of wheels are now made in consider-

* 'Mill Gearing,' by Thomas Box.

able quantities; such wheels are very strong and wear well. They can be made lighter and of finer pitch than in cast iron.

In a pair of unequal wheels the pinion wears the most and is the weakest in the teeth, because the root width is less than in the wheel; and when the pinion is comparatively small it will wear very much faster than the wheel, because its teeth are oftener in gear than those of the wheel, in proportion to the ratios of the diameters or numbers of teeth. It is usual in such cases to shroud it on one or both sides, this strengthens it 10 or 20 per cent., but adds nothing to its wear. Steel pinions are therefore often geared with cast-iron wheels. Shrouding may be applied to either spur or bevel gear.

All wheels required to run smoothly and accurately should have the teeth cut by machine: this ensures great accuracy and a perfectly shaped tooth. Such wheels may be run with hardly any clearance and deep in gear, and, with the modern milling machine constructed for this special work, are not costly. They are best cut out of the solid, and are cast with a plain rim for this purpose.

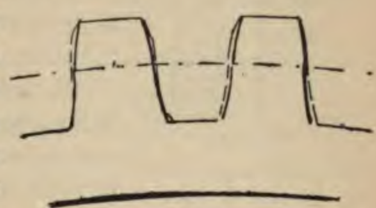


FIG. 230.

Pitching and trimming are also resorted to in large wheels, especially such as are built up with segments. This is done by marking off both faces of the wheel rim from a templet of the finished teeth, using the pitch line as guide; the surplus metal is then chipped off each side of the teeth to a straight edge and finished with a file (Fig. 230), but it is a tedious and expensive operation, which may be avoided entirely by careful pattern making and moulding. Most toothed wheels are now moulded by a radius rod and small segment with four or five teeth; so that the old system of full-sized patterns, stocked for every size of wheel required, is dying out, and any size of wheel can be moulded with a very small outlay for the pattern. Experience proves that for such gear wheels it is best and cheapest in the long run to purchase them from a foundry

where they are made a speciality. In ordinary mixed foundries but few of the moulders are really trustworthy in moulding toothed gear, and the most vexatious results may be expected even with good patterns. The teeth break down in the sand, and the moulder exercises his ingenuity and ideas of form in refixing the sand teeth in his own way. Where a full pattern is used, a slight taper or "draft" must be left on the teeth, so that when loosened they will leave the sand easily, and two or three loose teeth provided to be used for mending the mould teeth. The "draft" of the pinion pattern should be the opposite way to the wheel, so that the thick ends of one set of teeth run between the thin ends of the other set, and not *vice versâ* (see Figs. 231 and 232). With bevel gear this difficulty does not occur, as they leave the sand easily with their own taper.

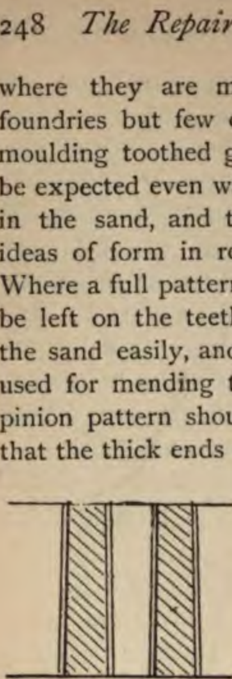


FIG. 231.


FIG. 232.

Helical or screw gear and double helical gear are also moulded by radius rod and segment pattern. A full pattern can be used and the teeth tapered to draw out of the sand screw-fashion.

Screw gear is used in lieu of bevel gear in situations where the shafts need not be on the same level, the teeth—with the shafts at 90°—being at an angle of 45°, and thus part of a multiple thread screw of same pitch as circumference, and if the teeth are cut by machine they work well, but must not be used to transmit considerable power, as there is a large amount of friction; they are usually for this reason—like worm gear—run in an oil box, out of sight, and must be well keyed up, or one of them may work along the shaft and get out of gear. The shafts also must be provided with collars to take the end strain due to the angle of the teeth.

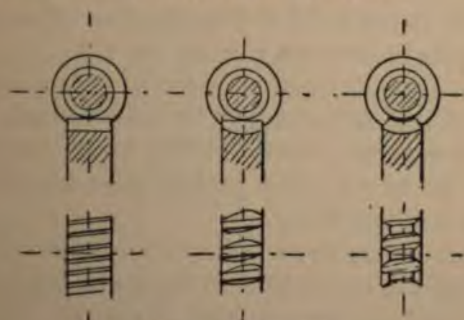
Double helical gear is becoming a favourite form of tooth gear for spur and bevel wheels, being in fact a near approach to rolling contact, one tooth coming into gear before the

previous one is out of gear. These wheels are 20 per cent. stronger than with plain spur teeth, and if well formed will run almost noiselessly. They cannot be cut by machine, however, therefore plain castings must be depended on. Single helical gear runs equally well, and can be cut in a machine, but there is considerable end strain on the shafts in opposite directions and risk of the wheels working along the shafts.

Raw hide pinions to gear with iron spur wheels and bevel wheels, are now much used both for quietness and lasting qualities.

Bevel and Mitre gears, when well made, run as well as spur gear, but require to be carefully lined up and geared, or they will be noisy and the teeth wear badly. The shafts must be in line and collars provided to both to keep the wheels in gear to the correct depth of teeth. It is best with this gear to make the adjoining bearings in one casting.

Skew Wheels.—Bevel gear runs equally well at any angle between the shafts. Skew spur or bevel gear becomes practically screw gear, there being more or less slip in the teeth endwise as they pass each other in gear. Skew wheels require accurate setting out, and the angle of skew must be equally divided between the two wheels, but such gears are more curious than useful and should be avoided.



Figs. 233, 234, 235.

Worm gear is used to greatly reduce speed in the shafts without several pairs of wheels intervening, and is a form of screw gear. There are three ways of gearing these, shown in Figs. 233, 234 and 235, the first with straight parallel teeth,

the second with hollow or curved teeth and straight points, the third with curved teeth and curved points. The first is the easiest to make and fit up, the third is the most difficult to gear, but gives by far the best grip and lasts the longest. The section of the screw thread and of the wheel teeth in the centre is the same as that of a spur wheel and rack of similar size. There is only one satisfactory and certain way to make the wheel pattern. First, turn and finish a pattern worm of steel, cut it into teeth as a hob and run it between the centres of a lathe, turn up the wood pattern, fit it on a centre pin to revolve easily, the pin being fixed to a bracket secured to the lathe slide rest, so that the wheel runs horizontally; then, after partly roughing out the teeth with a gouge, set the pair in gear and the hob will cut its own way into the wheel and form the teeth accurately, or the wheel casting may itself be cut into teeth in this way. This is expensive but reliable. A simpler way is to turn the worm first; cut plain spur teeth in a thin web in the centre of the wheel pattern, and gear the two together in temporary bearings (Fig. 236), then cut pieces to fit the outside face of the wheel and worm for two or three teeth, running the wheel by turning the worm until they work together smoothly; the spaces between these parts of the teeth can then be filled up and a templet made for the remaining teeth, finishing by revolving the wheel by its worm all round. The pattern must be divided in the centre to be moulded from.

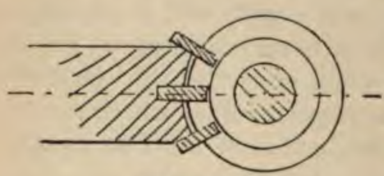


FIG. 236.

There is considerable end thrust on a worm shaft, equal in fact to the pressure transmitted to the worm wheel, and strong collars and bearings are provided to meet it. There is also great friction between the worm and wheel, frequently amounting to from 30 to 50 per cent., and the teeth wear very fast unless thoroughly lubricated. This is best done by dipping the wheel into an oil trough. Thick oil is best, especially if the speed is great, as otherwise the worm will throw it off.

Grease is of no use for worm gear, and of very little service on any toothed gear, because it is soon squeezed out by the pressure on the teeth, and does not run so as to get on to the working surfaces again. Thick oil is much better, but must be renewed at proper intervals. Tar and grease mixed are used on very heavy gear, as in such the great pressure would

FIG. 237.

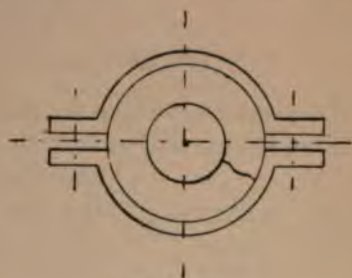


FIG. 238.

squeeze out thin oil. The thickness of a lubricant should therefore be proportionate to the pressure on the surfaces.

All toothed gear should be well protected, especially bevel gear, so that there is no possibility of accidents arising from workmen getting entangled in them. The Factory Act is very strict in this matter.

FIG. 239.

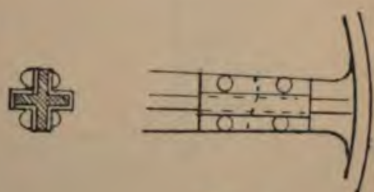


FIG. 240.

Injuries to wheels comprise the following:—split boss, arm cracked or broken, rim cracked, one or more teeth broken; these are repaired in the following ways.

Split boss, usually caused by keying up (see p. 74). Make two wrought-iron or steel rings, a shade smaller than the boss, and shrink them on hot (Fig. 237). Or, for a more temporary job, fix two pairs of clamps and bolts (Fig. 238).

Broken Arms.—These are of several sections and need different treatment (see Figs. 239, 240, 241 and 242). Fish

FIG. 241.

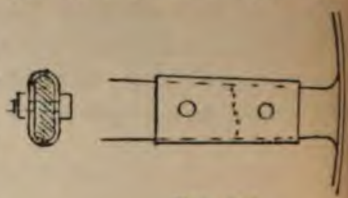


FIG. 242.

plates and bolts make the soundest and neatest jobs, as shown in the figures, and are within the capacity of any good smith and fitter, but the arms often break near the rim or boss, and then require other treatment. When broken at the rim a set screw can usually be tapped in, as shown in Fig. 243, with either section of arm. If broken at the boss, the fish plates should be then shaped as shown in Figs. 244 or 245, and bolted or set-screwed to the boss.

FIG. 243.

FIG. 244.

FIG. 245.

Cracked rim is most frequent with belt pulleys, and is generally easily repaired by a piece of plate riveted on the

under side. For this job use copper rivets, and countersink them on the outside. Spur wheel rims are repaired as Fig. 246, with wrought-iron fish plates of flat bar iron, shaped to the curve and fastened with set screws.

Broken teeth are comparatively of frequent occurrence, but can be satisfactorily repaired in nearly every case. If several

FIG. 246.

teeth are wholly or partly broken, shape out a dovetail recess across the wheel face, cast a brass or gun-metal segment and dovetail it in as shown in Fig. 247, driving it in tight from one side, and secure it with screws or copper rivets. Then file the

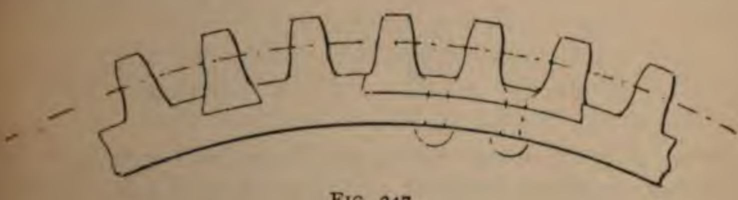


FIG. 247.

teeth to a templet made from the standing teeth of the wheel. For a single tooth proceed in the same way, but no rivets are needed if properly fitted and the ends peined up with the hammer, and afterwards filed off clean. Gun-metal teeth put in in this way in shaped dovetails are generally stronger than the iron ones they have replaced.

CHAPTER XX.

BELT, ROPE AND CHAIN GEAR.

Belts, ropes and chains are used under different conditions for driving machinery. For many reasons the belt is the best and simplest. It is very thin as compared with its width, wraps easily round the pulleys, and therefore wastes very little power. It has some amount of elasticity, will slip under great strain, sudden stoppage, &c., and has some advantages in shipping and unshipping that ropes and chains do not possess.

The disadvantages of belts are: they slip and creep on the pulleys, are rather expensive in renewals and repairs, and they stretch and require frequent tightening, especially when

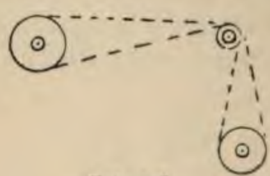


FIG. 248.

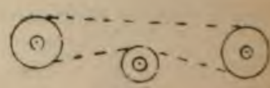


FIG. 249.

new. A great many substitutes have been introduced for leather as belting material, and some of them have obtained some success, but after all there is nothing to beat leather as yet, except in price. We find cotton webbing saturated with paint, camel hair belting, flax and other fibres. Of these a cotton web having a thickness of vulcanised fibre on the pulley face of the belt seems to have some advantage. For running in a fork, however, or on stepped cones or flanged pulleys, none of them are equal to leather, as they soon fray and cut on the edges, but for plain driving they will do fairly well. The fastenings most suitable for cotton and similar materials are rivets and plates; laces are difficult to thread through the material, single fasteners of the H and similar

forms tear through also. For leather, however, laces are the best.

Belts should not be bent both ways by such drives as Figs. 248 and 249, because it increases the wear and tear, and because the joints do not run well over the intermediate pulley. Short belts seldom run well except at low speeds, and very long belts drive unsteadily because the sag of the belt oscillates in a rhythmic way, and causes similar irregular

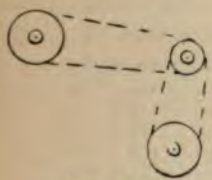


FIG. 250.

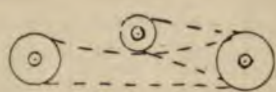


FIG. 251.

motion on the driven pulley. All such cranky drives are best avoided by using two belts and intermediate pulleys, as Figs. 250 and 251. Experience proves that they are the cheapest in the end. (See also p. 241.) Belt repairing is a saddler's job, the best and most permanent repair being a properly stitched splice, riveted also if necessary. Where fasteners are used, pieces of belt can always be put in at any time, but for these and laces also a proper punch should be used, as a hole cut by a knife always extends and bursts out.

WORKING STRAINS ON BELTS PER INCH OF WIDTH.

	lbs.
Ordinary single belts (leather)	50
Light double ,, ,, ...	70
Heavy ,, ,, ,, ...	90
Link belts $\frac{3}{8}$ inch thick	42
,, ,, $\frac{1}{2}$,, ...	48
,, ,, $\frac{5}{8}$,, ...	57
,, ,, $\frac{3}{4}$,, ...	66
,, ,, $\frac{7}{8}$,, ...	78
,, ,, 1 ,, ...	90

The strength of new leather varies from 3000 to 5000 lbs. per square inch of sectional area.

The coefficient of frictional contact of leather on cast-iron pulleys is ·42.

HORSE-POWER THAT DIFFERENT LEATHER BELTS WILL TRANSMIT PER INCH IN WIDTH AT VARIOUS SPEEDS.

Velocity of Belts per minute.	Kinds of Belts.								
	Best Oak-tanned Belts.			Best Link or Chain Belts.					
	Single Belts.	Light Double Belts.	Heavy Double Belts.	3/8	1/2	5/8	3/4	7/8	1
Feet.	Horse-power they will transmit.								
100	·15	·21	·27	·13	·15	·17	·20	·24	·27
200	·30	·42	·55	·25	·29	·35	·40	·47	·55
300	·45	·64	·82	·38	·44	·52	·60	·71	·82
400	·61	·85	1·09	·51	·58	·69	·80	·95	1·09
500	·76	1·06	1·36	·64	·73	·86	1·00	1·18	1·36
600	·91	1·27	1·64	·76	·87	1·04	1·20	1·42	1·64
700	1·06	1·49	1·91	·82	1·02	1·21	1·40	1·65	1·91
800	1·21	1·70	2·18	·92	1·16	1·38	1·60	1·89	2·18
900	1·36	1·91	2·45	1·05	1·31	1·55	1·80	2·13	2·45
1000	1·51	2·12	2·73	1·27	1·45	1·73	2·00	2·36	2·73
1100	1·67	2·33	3·00	1·40	1·60	1·90	2·20	2·60	3·00
1200	1·82	2·55	3·27	1·53	1·75	2·07	2·40	2·84	3·27
1300	1·97	2·76	3·55	1·65	1·89	2·25	2·60	3·07	3·55
1400	2·12	2·97	3·82	1·78	2·04	2·42	2·80	3·31	3·82
1500	2·27	3·18	4·09	1·91	2·18	2·59	3·00	3·55	4·09
1600	2·42	3·39	4·36	2·04	2·33	2·76	3·20	3·78	4·36
1700	2·58	3·61	4·64	2·16	2·47	2·94	3·40	4·02	4·64
1800	2·73	3·82	4·91	2·29	2·62	3·11	3·60	4·25	4·91
1900	2·88	4·03	5·18	2·42	2·76	3·28	3·80	4·49	5·18
2000	3·03	4·24	5·45	2·55	2·91	3·45	4·00	4·73	5·45
2100	3·18	4·45	5·73	2·67	3·05	3·63	4·20	4·96	5·73
2200	3·33	4·67	6·00	2·80	3·20	3·80	4·40	5·20	6·00
2300	3·49	4·88	6·27	2·93	3·35	3·97	4·60	5·44	6·27
2400	3·64	5·09	6·55	3·05	3·49	4·15	4·80	5·67	6·55
2500	3·79	5·30	6·82	3·18	3·64	4·32	5·00	5·91	6·82
2600	3·94	5·52	7·09	3·24	3·78	4·49	5·20	6·15	7·09
2700	4·09	5·73	7·36	3·28	3·85	4·66	5·40	6·38	7·36
2800	4·24	5·94	7·64	3·31	3·86	4·73	5·60	6·62	7·64
2900	4·39	6·15	7·91	3·32	3·87	4·78	5·80	6·85	7·91
3000	4·50	6·36	8·18	3·31	3·86	4·75	5·97	7·09	8·18
3100	4·60	6·58	8·45	3·30	3·85	4·73	5·96	7·33	8·45
3200	4·69	6·79	8·70	3·28	3·82	4·71	5·94	7·37	8·73
3300	4·77	7·00	8·86	3·24	3·77	4·70	5·92	7·35	8·88
3400	4·84	7·21	8·96	3·19	3·71	4·64	5·87	7·32	8·86
3500	4·90	7·31	9·06	3·13	3·61	4·50	5·78	7·26	8·80
3600	4·95	7·40	9·16	3·05	3·50	4·37	5·67	7·16	8·73
3700	4·99	7·48	9·24	2·96	3·39	4·26	5·55	7·01	8·58
3800	5·03	7·54	9·29	2·84	3·28	4·15	5·41	6·87	8·41
3900	5·06	7·60	9·34	2·72	3·13	4·02	5·20	6·70	8·27
4000	5·08	7·64	9·37	2·58	2·95	3·84	5·01	6·48	8·04

Round belts for V-grooves for foot lathes, &c., are either of gut with screwed hook and eye, or of leather with hook and eye, or wire staple joint, or of a gutta-percha cord and a welded joint. The latter has given most satisfaction in our practice, as it is easily repaired, shortened or a piece put in, without thick joints, by simply softening the gutta-percha and sticking the ends (previously cut to a scarf) together. Hooks and eyes often tear off, and wire staples pull out, causing waste of time to refix and frequent renewals of belting.

Rope gear is now used to a great extent for the main drives in large mills, electrical works, &c. The pulleys for these drives are turned on the face with a number of rope V-grooves. Sometimes a single endless rope serves for each drive; in others the rope is carried several times round both pulleys, the last lap being crossed over the others diagonally and spliced. For this reason the distance between the shafts

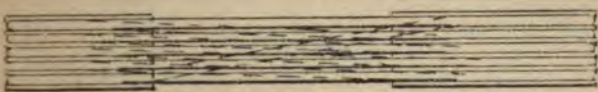


FIG. 252.

must be considerable (from 30 to 60 feet) or the rope may work out of the groove on the last (diagonal) lap. This is prevented by fixing a guide pulley with a deep turned V-groove in such a position as to direct the *going on* part of the diagonal lap in a line with the pulley groove, so that it leads fair in going on to its pulley (Fig. 252).

Ropes are run slack, depending for their bite on the grip of the V-groove and the weight of the rope, combined with a long circumferential bite. Pulleys, therefore, must not be small in diameter; ropes do not need taking up so often as belts. If possible the slack side should be the upper one, both with ropes and belts, they then get a longer circumferential grip on the pulleys than when run the other way (Figs. 253 and 254).

The H.P. of rope gearing is found thus: Multiply the square of the circumference of the rope in inches by the

velocity in feet per minute, and by the number of ropes less one, and divide the quotient by 4000.

The circumference of the required rope is found thus: Multiply the indicated H.P. by 4000, divide the result by the velocity in feet per minute, multiplied by the number of ropes less one, and find the square root of the quotient for the diameter of rope in inches.

V-grooves should be turned to an angle of 40°, and the rope must not touch the bottom of the groove. Some little allowance must be made in depth of groove as the rope compresses to a triangular section in working.

The working tension of ropes should not exceed 250 lbs. per square inch of sectional area. The velocity of ropes may be between 3000 and 6000 feet per minute; of belts, any speeds up to 3000 feet per minute.

Cotton ropes are almost universally used for rope drives, and they are lubricated with blacklead and tallow mixed into

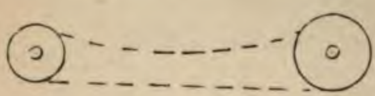


FIG. 253.

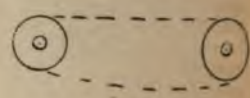


FIG. 254.

a paste. The diameter of rope varies from 1 inch to 1¾ inches; the minimum diameters of pulleys varying from 18 inches with 1-inch ropes to 36 inches with 1¾-inch ropes.

There is more friction in rope driving than in belt driving, because in the former the bending of the ropes and the wedging grip in the V-grooves are greater than the bending of a thin belt and its surface tension on the pulley, but the difference is not great, while the belt will considerably outlive the rope, but is in itself more costly. In comparing cost, however, the pulleys and connections must be taken into account, and in this respect the grooved turned fly pulleys and guide wheels cost considerably more than plain belt pulleys. The ends are joined by the sailor's ordinary short splice.

Ropes have some advantage over belts in the width of the

HORSE POWER THAT GOOD COTTON DRIVING ROPES WILL TRANSMIT AT VARIOUS SPEEDS.

Velocity in feet per minute.	Diameter of ropes in inches.								
	½	⅝	¾	⅞	1	1¼	1½	1¾	2
	Horse power they will transmit.								
600	·84	1·30	1·91	2·60	3·43	5·30	7·69	10·40	13·52
700	·98	1·52	2·23	3·03	4·00	6·18	8·96	12·12	15·75
800	1·12	1·73	2·54	3·45	4·56	7·05	10·22	13·82	17·96
900	1·26	1·94	2·86	3·88	5·12	7·92	11·48	15·52	20·17
1000	1·39	2·15	3·16	4·30	5·67	8·76	12·72	17·18	22·34
1100	1·53	2·35	3·47	4·71	6·22	9·61	13·94	18·83	24·48
1200	1·66	2·56	3·77	5·12	6·76	10·44	15·15	20·47	26·61
1300	1·79	2·76	4·07	5·53	7·29	11·27	16·35	22·10	28·73
1400	1·92	2·96	4·36	5·93	7·83	12·10	17·55	23·72	30·83
1500	2·05	3·16	4·64	6·32	8·34	12·89	18·70	25·27	32·86
1600	2·18	3·36	4·94	6·74	8·86	13·70	19·88	26·86	34·92
1700	2·30	3·55	5·22	7·10	9·37	14·48	21·01	28·39	36·90
1800	2·42	3·74	5·50	7·47	9·86	15·25	22·12	29·89	38·85
1900	2·54	3·92	5·76	7·83	10·34	15·97	23·18	31·32	40·71
2000	2·66	4·10	6·03	8·20	10·82	16·72	24·26	32·79	42·62
2100	2·77	4·27	6·29	8·54	11·28	17·43	25·29	34·17	44·42
2200	2·88	4·45	6·55	8·90	11·75	18·16	26·35	35·60	46·29
2300	2·99	4·62	6·80	9·24	12·19	18·84	27·34	36·94	48·03
2400	3·10	4·78	7·04	9·56	12·62	19·51	28·31	38·26	49·73
2500	3·20	4·94	7·28	9·89	13·05	20·17	29·26	39·55	51·41
2600	3·30	5·09	7·50	10·18	13·44	20·77	30·14	40·73	52·96
2700	3·39	5·24	7·71	10·48	13·83	21·37	31·00	41·90	54·47
2800	3·48	5·38	7·92	10·75	14·20	21·94	31·84	43·02	55·93
2900	3·57	5·51	8·12	11·03	14·56	22·50	32·64	44·11	57·35
3000	3·66	5·65	8·31	11·30	14·91	23·04	33·44	45·18	58·74
3100	3·74	5·78	8·50	11·56	15·25	23·57	34·20	46·22	60·08
3200	3·83	5·90	8·69	11·81	15·59	24·09	34·95	47·23	61·40
3300	3·90	6·01	8·85	12·02	15·87	24·53	35·59	48·10	62·53
3400	3·96	6·12	9·01	12·23	16·15	24·96	36·21	48·94	63·62
3500	4·03	6·22	9·15	12·44	16·42	25·37	26·81	49·75	64·67
3600	4·09	6·31	9·29	12·63	16·67	25·76	37·38	50·51	65·66
3700	4·15	6·41	9·43	12·81	16·91	26·13	37·92	51·24	66·62
3800	4·20	6·48	9·53	12·95	17·10	26·43	38·35	51·82	67·36
3900	4·25	6·56	9·65	13·12	17·32	26·76	38·83	52·48	68·22
4000	4·29	6·62	9·75	13·24	17·48	27·01	39·20	52·97	68·86
4100	4·33	6·68	9·83	13·36	17·63	27·25	39·53	53·42	69·44
4200	4·36	6·73	9·91	13·46	17·77	27·46	39·84	53·84	69·99
4300	4·39	6·78	9·98	13·55	17·89	27·65	40·11	54·11	70·47
4400	4·41	6·80	10·01	13·60	17·95	27·75	40·26	54·40	70·72
4500	4·42	6·80	10·04	13·64	18·00	27·82	40·36	54·55	70·91
4600	4·43	6·83	10·06	13·66	18·03	27·87	40·44	54·64	71·04
4700	4·43	6·84	10·07	13·67	18·05	27·90	40·48	54·70	71·10
4800	4·43	6·84	10·07	13·67	18·05	27·90	40·48	54·70	71·10
4900	4·43	6·83	10·06	13·66	18·03	27·87	40·44	54·64	71·04
5000	4·41	6·80	10·01	13·60	17·95	27·74	40·25	54·40	70·70

pulleys required to transmit any given power, the difference being probably 20 to 25 per cent. in favour of the ropes.

The greatest cause of wear in cotton ropes thus employed is the internal friction among the fibres due to frequent bending under strain. This will, evidently, be proportionately greater with large ropes and small pulleys than with small ropes and large pulleys. The grooves in the latter must always be turned to prevent external wear of the ropes.

Speed and Working Strain on Ropes.—The breaking strain of good cotton ropes is about 4 tons or 9000 lbs. per square inch, and the makers allow a working strain of about 300 lbs. per square inch of sectional area. Of this amount about 20 per cent. or 60 lbs. is absorbed in overcoming back tension, wedging of rope, &c., leaving 240 lbs. for centrifugal force and transmission of power.

Strain due to Centrifugal Force.—The strain arising from this cause increases with the square of the velocity, and imposes a limit on the speed beyond which it is not economical to go. This limit for cotton ropes is about 4700 feet per minute.

PROPORTIONS OF COTTON DRIVING ROPES AND PULLEYS.

Diam. of Ropes.	Area of Rope.	Weight per foot.	Ordinary working tension, including centrifugal force.	Velocity of Ropes, 4,700 feet per minute (their most effective speed).			Rope Pulleys.	
				Strain due to centrifugal force.	Effective Tension.	Power each Rope will transmit.	Centre to centre of Ropes.	Diam. of smallest Pulley.
in.	in.	lbs.	lbs.	lbs.	lbs.	H.P.	in.	in.
$\frac{1}{2}$	·1963	·081	47	16	31	4·43	$\frac{7}{8}$	15
$\frac{5}{8}$	·3067	·125	72	24	48	6·84	1	18
$\frac{3}{4}$	·4417	·184	106	35	71	10·07	$1\frac{1}{8}$	22
$\frac{7}{8}$	·6013	·25	144	48	96	13·67	$1\frac{5}{16}$	26
1	·7854	·33	190	63	127	18·05	$1\frac{1}{2}$	30
$1\frac{1}{4}$	1·2272	·51	294	98	196	27·90	$1\frac{13}{16}$	37
$1\frac{1}{2}$	1·7671	·74	426	142	284	40·48	$2\frac{1}{8}$	45
$1\frac{3}{4}$	2·4053	1·00	576	192	384	54·70	$2\frac{1}{2}$	52
2	3·1416	1·30	750	250	500	71·10	$2\frac{3}{4}$	60

Life of Cotton Driving Ropes.—The average life of cotton ropes properly put on and well cared for is about twelve years, while some ropes have remained in good order after the lapse of seventeen years.

Wire rope transmission—a method of driving through long distances by a high speed rope of small diameter and light tension. It is used to drive machinery at a distance from the motor, and to convey materials in buckets or small suspended cars, running continuously, and is successful and fairly economical over long distances; several installations are at work extending in lines 3 miles long. Wire ropes are used invariably, and some engineers give the preference to iron wire as being more durable than steel: this is probably due to irregular temper in the latter.

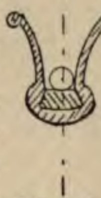


FIG. 255.

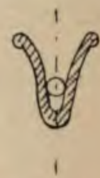


FIG. 256.

The pulleys are V-grooved, with a wood or leather-on-edge bottom to the grooves (Fig. 255), let into a dovetail recess, and the rope is not gripped except in the case of driving

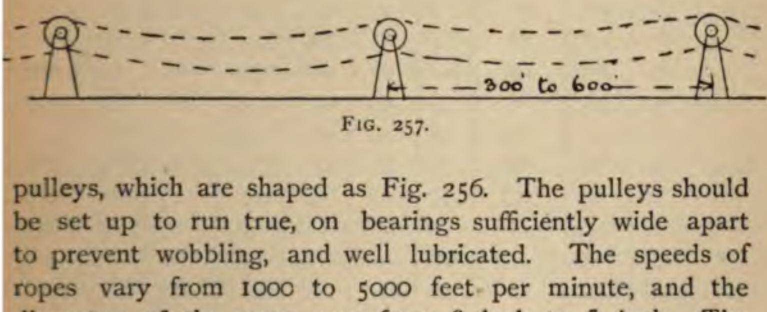


FIG. 257.

pulleys, which are shaped as Fig. 256. The pulleys should be set up to run true, on bearings sufficiently wide apart to prevent wobbling, and well lubricated. The speeds of ropes vary from 1000 to 5000 feet per minute, and the diameters of the ropes vary from $\frac{3}{8}$ inch to $\frac{7}{8}$ inch. The driving tension should be on the lower rope, and the ropes may be carried up and down in any direction over hills, buildings, &c., but the more direct the course the less will be the loss in friction.

The guide pulleys are fixed about 40 feet apart for $\frac{3}{8}$-inch ropes and 100 feet for $\frac{7}{8}$-inch ropes, and do not require very substantial supports; but when separate relays are used for

FLEXIBLE STEEL WIRE HAWSERS AND CABLES COMPARED WITH HEMP AND CHAIN.

Flexible Steel Wire Hawsers and Cables.				Chain Cable.				Tarred Hemp Rope.		
Size, circumference.	Weight per fathom.	Guaranteed breaking strain.	Diameter of barrel or sheave round which it may be worked.	Size.	Weight per fathom.	Proof strain.	Breaking strain.	Size.	Weight per fathom.	Breaking strain.
in.	lbs.	tons.	in.	in.	lbs.	tons.	tons.	in.	lbs.	tons.
12	115	320	72							
11	97	270	66							
10	80	220	60							
9	65	180	54							
8	53	150	48	$2\frac{5}{16}$	280	$96\frac{1}{4}$	$134\frac{3}{4}$	25	146	125
$7\frac{1}{2}$	47	130	45	$2\frac{3}{16}$	256	$86\frac{1}{8}$	$120\frac{1}{2}$	24	134	115
7	41	116	42	$2\frac{1}{16}$	231	$76\frac{1}{2}$	$107\frac{1}{10}$	23	123	106
$6\frac{1}{2}$	37	102	39	$1\frac{15}{16}$	204	$67\frac{1}{2}$	$94\frac{1}{2}$	21	106	89
6	33	88	36	$1\frac{3}{4}$	166	$55\frac{1}{8}$	$77\frac{1}{8}$	19	84	72
$5\frac{1}{2}$	28	74	33	$1\frac{5}{8}$	143	$47\frac{1}{2}$	$66\frac{1}{2}$	17	67	60
5	$23\frac{1}{2}$	64	30	$1\frac{7}{16}$	112	$37\frac{1}{8}$	$55\frac{1}{2}$	15	56	50
$4\frac{1}{2}$	15	39	27	$1\frac{1}{8}$	68	$22\frac{3}{4}$	$34\frac{1}{8}$	13	39	34
4	12	33	24	1	54	18	27	12	33	29
$3\frac{1}{2}$	9	26	21	$\frac{15}{16}$	48	$15\frac{8}{10}$	$23\frac{7}{10}$	11	28	$24\frac{1}{2}$
$3\frac{1}{4}$	8	22	$19\frac{1}{2}$	$\frac{13}{16}$	35	$11\frac{7}{8}$	$17\frac{8}{10}$	10	23	20
3	7	18	18	$\frac{12}{16}$	30	$10\frac{1}{8}$	$15\frac{1}{8}$	9	19	$16\frac{1}{4}$
$2\frac{3}{4}$	$5\frac{1}{2}$	15	$16\frac{1}{2}$	$\frac{11}{16}$	25	$8\frac{1}{2}$	$12\frac{3}{4}$	$8\frac{1}{2}$	16	14
$2\frac{1}{2}$	$4\frac{1}{2}$	12	15	..	..	..	..	$7\frac{1}{2}$	13	$11\frac{1}{2}$
$2\frac{1}{4}$	$3\frac{3}{4}$	9	$13\frac{1}{2}$	$\frac{10}{16}$	21	7	$9\frac{1}{2}$	$6\frac{1}{2}$	$11\frac{1}{4}$	10
2	$2\frac{3}{4}$	7	12	..	..	..	..	$5\frac{3}{4}$	9	8
$1\frac{3}{4}$	2	$5\frac{1}{2}$	$10\frac{1}{2}$	$\frac{9}{16}$	17	$5\frac{1}{2}$	$7\frac{1}{4}$	5	$6\frac{1}{2}$	6
$1\frac{1}{2}$	$1\frac{3}{4}$	4	9	..	..	..	..	4	4	4
$1\frac{1}{4}$	1	$2\frac{1}{2}$	$7\frac{1}{2}$	$\frac{1}{2}$	14	$4\frac{1}{2}$	6	$3\frac{1}{2}$	$3\frac{1}{4}$	$2\frac{3}{4}$
1	$\frac{3}{4}$	$1\frac{3}{4}$	6	..	..	..	..	$2\frac{3}{4}$	2	$1\frac{3}{4}$

Where the rope only passes over a sheave, the diameter of the sheave may be one-sixth less than where the rope takes an entire turn round.

In all cases the diameter of both barrels and sheaves should be as large as practicable.

GALVANISED STEEL AND IRON WIRE ROPE FOR RIGGING PURPOSES.

Steel Wire Rope for Standing Rigging.					Iron Wire Rope for Standing Rigging.		
Size, circumference.	No. of wires in a strand.	No. of strands in a rope.	Weight per fathom.	Breaking strain.	Weight per fathom.	Breaking strain.	Size.
inches.			lbs.	tons.	lbs.	tons.	inches.
8	19	6	62	160	$51\frac{3}{4}$	$44\frac{5}{20}$	8
$7\frac{1}{2}$	19	6	53	141	$46\frac{3}{4}$	$41\frac{5}{20}$	$7\frac{1}{2}$
7	19	6	46	123	$42\frac{1}{2}$	$36\frac{5}{20}$	7
$6\frac{1}{2}$	19	6	40	106	$36\frac{3}{4}$	$32\frac{1}{20}$	$6\frac{1}{2}$
6	19	6	34	90	$31\frac{1}{2}$	$27\frac{3}{20}$	6
$5\frac{1}{2}$	19	6	28	76	$26\frac{1}{2}$	$22\frac{1}{2}$	$5\frac{1}{2}$
5	19	6	23	63	$21\frac{1}{2}$	$18\frac{11}{20}$	5
$4\frac{1}{2}$	19	6	19	51	$17\frac{3}{4}$	$15\frac{15}{20}$	$4\frac{1}{2}$
4	7	6	$15\frac{1}{2}$	40	$13\frac{1}{4}$	$11\frac{16}{20}$	4
$3\frac{1}{2}$	7	6	$11\frac{1}{2}$	32	$10\frac{3}{4}$	$9\frac{7}{20}$	$3\frac{1}{2}$
$3\frac{1}{4}$	7	6	10	27	$9\frac{1}{2}$	$8\frac{1}{2}$	$3\frac{1}{4}$
3	7	6	8	24	$8\frac{1}{2}$	$7\frac{3}{20}$	3
$2\frac{3}{4}$	7	6	7	19	$7\frac{1}{4}$	$6\frac{1}{2}$	$2\frac{3}{4}$
$2\frac{1}{2}$	7	6	6	16	$5\frac{3}{4}$	$4\frac{1}{2}$	$2\frac{1}{2}$
$2\frac{1}{4}$	7	6	5	13	$4\frac{3}{4}$	4	$2\frac{1}{4}$
2	7	6	4	10	$3\frac{1}{2}$	3	2
$1\frac{3}{4}$	7	6	3	8	3	$2\frac{9}{20}$	$1\frac{3}{4}$
$1\frac{1}{2}$	7	6	2	6	$2\frac{1}{2}$	$1\frac{14}{20}$	$1\frac{1}{2}$

transmitting power only, the distances are increased to from 300 to 600 feet, as Fig. 257. The grooves and ropes are occasionally lubricated with hot tar. The cost of this plant for transmitting power as compared with shafting is about as 1 to 15, and compared with belting as 1 to 10, and the efficiency nearly in the reverse ratio for long distances.

The working tension on the rope should not exceed $\frac{1}{20}$ of its breaking strain.

There is no trouble in keeping a rope transmission gear in good running order. The ropes will last from six months to two years and are easily replaced.

LLOYD'S LIST FOR STEAM VESSELS.

Ship's tonnage.	Numbers for Iron Vessels.	Stream, Chain, or Steel Wire.				Towline: Hemp or Steel Wire				Hawsers and Warps. 90 fathoms of each.	
		Chain.		Steel Wire.		Hemp.		Steel Wire.			
				Size.	Breaking Test.			Size.	Breaking Test.		
tons.		fath.	in.	in.	tons.	fath.	in.	in.	tons.	in.	in.
75	2750	45	$\frac{8}{16}$	..	..	75	$5\frac{1}{2}$			3	
112	3750	45	$\frac{9}{16}$	2	7	75	6			4	
150	4630	45	$\frac{9}{16}$	2	7	75	6			4	
188	5420	45	$\frac{10}{16}$	$2\frac{1}{4}$	$9\frac{1}{2}$	75	$6\frac{1}{2}$			4	
225	6150	45	$\frac{10}{16}$	$2\frac{1}{4}$	$9\frac{1}{2}$	75	7			5	
262	6840	45	$\frac{11}{16}$	$2\frac{3}{4}$	$15\frac{1}{2}$	75	$7\frac{1}{2}$			$5\frac{1}{2}$	
300	7490	60	$\frac{11}{16}$	$2\frac{3}{4}$	$15\frac{1}{2}$	75	$7\frac{1}{2}$			$5\frac{1}{2}$	
375	8670	60	$\frac{12}{16}$	$2\frac{3}{4}$	$15\frac{1}{2}$	75	8			6	
450	9770	60	$\frac{13}{16}$	3	18	75	$8\frac{1}{2}$			$6\frac{1}{2}$	
525	10790	60	$\frac{13}{16}$	3	18	75	$8\frac{1}{2}$			$6\frac{1}{2}$	4
600	11740	60	$\frac{14}{16}$	$3\frac{1}{4}$	22	90	9			7	5
675	12620	60	$\frac{14}{16}$	$3\frac{1}{4}$	22	90	9			7	5
750	13450	60	$\frac{15}{16}$	$3\frac{1}{2}$	26	90	$9\frac{1}{2}$			$7\frac{1}{2}$	$5\frac{1}{2}$
900	15120	75	$\frac{15}{16}$	$3\frac{1}{2}$	26	90	10	$3\frac{1}{4}$	22	8	$5\frac{1}{2}$
1050	16720	75	1	$3\frac{3}{4}$	29	90	10	$3\frac{1}{4}$	22	8	6
1200	18260	75	1	$3\frac{3}{4}$	29	90	10	$3\frac{1}{4}$	22	$8\frac{1}{2}$	6
1350	19780	75	$1\frac{1}{16}$	4	33	90	11	$3\frac{1}{2}$	26	9	7
1500	21280	75	$1\frac{1}{16}$	4	33	90	11	$3\frac{1}{2}$	26	9	$7\frac{1}{2}$
1800	24220	75	$1\frac{2}{16}$	$4\frac{1}{4}$	35	90	12	4	33	$9\frac{1}{2}$	$7\frac{1}{2}$
2100	27140	75	$1\frac{2}{16}$	$4\frac{1}{4}$	35	100	12	4	33	$9\frac{1}{2}$	8
2400	30020	90	$1\frac{2}{16}$	$4\frac{1}{4}$	35	100	12	4	33	10	$8\frac{1}{2}$
2700	32820	90	$1\frac{3}{16}$	$4\frac{1}{2}$	39	120	12	4	33	10	$8\frac{1}{2}$
3000	35450	90	$1\frac{3}{16}$	$4\frac{1}{2}$	39	120	13	$4\frac{1}{2}$	39	10	9
3500	39600	90	$1\frac{3}{16}$	$4\frac{1}{2}$	39	120	13	$4\frac{1}{2}$	39	11	9
4000	43600	90	$1\frac{4}{16}$	$4\frac{3}{4}$	47	120	14	$4\frac{3}{4}$	47	12	10
4500	47400	90	$1\frac{4}{16}$	$4\frac{3}{4}$	47	120	14	$4\frac{3}{4}$	47	12	10
5000	51000	90	$1\frac{5}{16}$	5	59	120	15	5	59	12	10
5500	55000	120	$1\frac{5}{16}$	5	59	130	15	5	59	13	11
6000	59000	120	$1\frac{5}{16}$	5	59	130	15	5	59	13	11
6500 to 7000	63000 to 70000	120	$1\frac{6}{16}$	$5\frac{1}{4}$	71	130	16	$5\frac{1}{4}$	71	13	11

LLOYD'S LIST FOR SAILING VESSELS.

Numbers for Iron Vessels.	Stream, Chain or Steel Wire.				Towline: Hemp or Steel Wire.				Hawsers and Warps. 90 fathoms of each.	
	Chain.		Steel Wire.		Hemp.		Steel Wire.			
			Size.	Breaking Test.			Size.	Breaking Test.		
	fath.	in.	in.	tons.	faths.	in.	in.	tons.	in.	in.
1900	45	$\frac{7}{16}$			75	5			3	
2500	45	$\frac{8}{16}$			75	$5\frac{1}{2}$			3	
3100	45	$\frac{8}{16}$			75	$5\frac{1}{2}$			3	
3650	45	$\frac{8}{16}$			75	6			$3\frac{1}{2}$	
4200	45	$\frac{9}{16}$	2	7	75	$6\frac{1}{2}$			4	
4700	45	$\frac{9}{16}$	2	7	75	$6\frac{1}{2}$			4	
5150	45	$\frac{10}{16}$	$2\frac{1}{4}$	$9\frac{1}{2}$	75	7			4	
6000	45	$\frac{10}{16}$	$2\frac{1}{4}$	$9\frac{1}{2}$	75	$7\frac{1}{2}$			5	
6800	60	$\frac{11}{16}$	$2\frac{3}{4}$	$15\frac{1}{2}$	75	8			$5\frac{1}{2}$	
7550	60	$\frac{11}{16}$	$2\frac{3}{4}$	$15\frac{1}{2}$	75	8			$5\frac{1}{2}$	
8250	60	$\frac{12}{16}$	$2\frac{3}{4}$	$15\frac{1}{2}$	75	$8\frac{1}{2}$			6	
8900	60	$\frac{12}{16}$	$2\frac{3}{4}$	$15\frac{1}{2}$	75	9			$6\frac{1}{2}$	
9600	60	$\frac{13}{16}$	3	18	75	$9\frac{1}{2}$			7	
10800	60	$\frac{13}{16}$	3	18	90	10	$3\frac{1}{4}$	22	7	4
12000	60	$\frac{14}{16}$	$3\frac{1}{4}$	22	90	10	$3\frac{1}{4}$	22	8	5
13200	75	$\frac{14}{16}$	$3\frac{1}{4}$	22	90	10	$3\frac{1}{4}$	22	8	5
14400	75	$\frac{15}{16}$	$3\frac{1}{2}$	26	90	$10\frac{1}{2}$	$3\frac{1}{4}$	22	9	$5\frac{1}{2}$
15500	75	$\frac{15}{16}$	$3\frac{1}{2}$	26	90	$10\frac{1}{2}$	$3\frac{1}{4}$	22	9	$5\frac{1}{2}$
17600	75	1	$3\frac{3}{4}$	29	90	11	$3\frac{1}{2}$	26	$9\frac{1}{2}$	6
19600	75	1	$3\frac{3}{4}$	29	90	11	$3\frac{1}{2}$	26	10	6
21600	75	$1\frac{1}{16}$	4	33	90	11	$3\frac{1}{2}$	26	$10\frac{1}{2}$	$6\frac{1}{2}$
23400	75	$1\frac{1}{16}$	4	33	90	12	4	33	11	7
25100	100	$1\frac{2}{16}$	$4\frac{1}{4}$	35	90	12	4	33	11	7
29400	120	$1\frac{3}{16}$	$4\frac{1}{4}$	35	90	13	$4\frac{1}{2}$	39	12	8
33400	120	$1\frac{3}{16}$	$4\frac{1}{2}$	39	90	13	4	39	12	8

Chain Gear.—For comparatively slow speeds, and where a ive drive is desirable, chains and sprocket wheels are h used. Such drives include elevators and travelling eyors of all kinds, water lifters, such as chain pumps and

bucket pumps; shaft driving for pug mills, pumps, grinding mills, screens, &c.

In all cases specially shaped sprocket wheels are required, and the shape and pitch of teeth is very important.

STRENGTH AND WEIGHT OF IRON CRANE CHAINS. Short Link, B.B.B. Quality.

Diameter.	Safe Load.		Breaking Load.		Weight per fathom (6 feet).
in.	tons.	cwts.	tons.	cwts.	lbs.
$\frac{3}{16}$	..	6	1	5	3
$\frac{1}{4}$	..	11	2	5	$4\frac{1}{2}$
$\frac{5}{16}$	..	17	3	7	$6\frac{1}{2}$
$\frac{3}{8}$	1	4	4	15	9
$\frac{7}{16}$	1	12	6	10	12
$\frac{1}{2}$	2	1	8	5	16
$\frac{9}{16}$	2	11	10	5	20
$\frac{5}{8}$	3	1	12	5	25
$\frac{11}{16}$	3	12	14	10	31
$\frac{3}{4}$	4	7	17	10	37
$\frac{13}{16}$	5	0	20	0	42
$\frac{7}{8}$	5	11	22	5	48
$\frac{15}{16}$	6	7	25	10	53
1	7	2	28	10	60
$1\frac{1}{16}$	7	17	31	10	72
$1\frac{1}{8}$	8	12	34	10	90
$1\frac{1}{4}$	13	4	42	15	105
$1\frac{1}{2}$	14	7	57	10	120
$1\frac{3}{4}$	19	7	79	10	160
2	26	0	104	10	220

B.B. quality is about 20 per cent. weaker than above table.
B. quality is about 30 per cent. weaker than above table.
Safe working load is one-fourth the breaking strain.

The forms of chains most used are the "stud-link" and the "short-link." The proportions of the links are the same for all sizes, "stud-links" having a length over all of about 6 diameters, and a width of about $3\frac{1}{2}$ diameters, the corresponding proportions of the "short-link" being 5 and $3\frac{1}{2}$. The *proof* and *working* stress of "short-links" are only two-thirds those of "stud-links."

If d = diameter of iron in eighths of an inch, then:
Safe loads in tons of B.B. "short-link" $= d^2 \div 10$.
Weight per fathom of "short-link" $= d^2$ lbs.
Admiralty proof stress (twice working stress) $= \frac{3}{16} d^2$.
Elswick test 10 per cent. above Admiralty proof.

Chains for these drives include ordinary long or short link itched chain, flat linked chains, geared chains, and several arieties of patent drive chains, see Figs. 258 to 267. Most f the latter are made to detach at will at any link by bending he chain to an acute angle such as it can never occupy when at work, Figs. 266 and 267. The other types of chains can only be detached by taking out a joint pin or breaking a link.

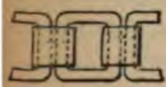


Fig. 258.

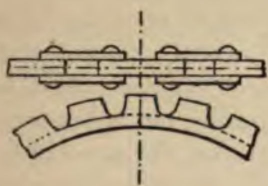


Fig. 259.

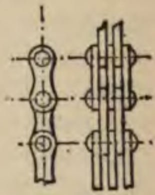


Fig. 260.

Fig. 261.

Fig. 262.

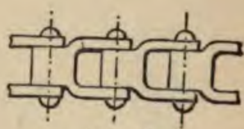


Fig. :63

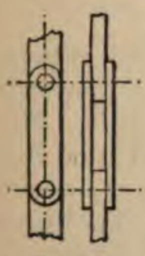


Fig. 264.

Fig. 265.

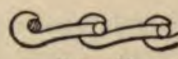


Fig. 266.

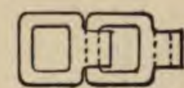


Fig. 267.

Sprocket wheels generally need not be of large diameter, but at least four links should be in gear at once. The chains need not be tight, but when they become too slack may be liable to slip or drive unsteadily. It is usual either to remove the shafts further apart, for which an adjustment of their bearings is often provided ; or to take out one or more links and so shorten the chain. It must be remembered that every link or joint wears, adding to the length of the chain, in-

creasing the pitch of its links. Lubrication, therefore, must be applied specially to the joints, and also to the sprocket teeth to be effectual. Plastering the chain with grease is of little use; it must be oiled, and the best and most effectual plan is to allow a part of it to dip into an oil bath, providing a trough to catch the drip and return it to the bath.

Chain wheels for ordinary chains are made as Fig. 268; the wear on these takes place at the shoulders A, by rubbing contact with the shoulders of the links. There must be no twist in a chain running over a sprocket wheel, or it will ride out of gear. There are one or two patent forms of chain wheels with removable sprockets, but in the ordinary way new wheels are provided when the old ones are much worn. The difficulty with these is always the variation of pitch. The wear of the wheel does not affect the pitch, but the chain

FIG. 268.

FIG. 269.

invariably increases its pitch by wear and stretching, often to a serious extent, so much so as frequently to require new wheels, or a new chain to fit the old wheels. The wear of a link is shown in Fig. 269 at A and B. That at A lengthens the pitch and weakens the chain, and that at B does not affect the pitch, but makes the chain a loose fit, with a tendency to jam in the wheel. It is customary, therefore, to make new wheels long in the pitch to the extent of about 5 per cent. If the wheel is so large in diameter as to have many links in gear at once, this cannot be done, or the chain will be out of gear in places at first. The fact is that ordinary chain is not suitable for driving at all if it will be much used, and therefore wear much. The only other precaution that can be taken is to have the chains made of hard iron and have them tested, which will stretch them so that they will not be likely to stretch further. Soft iron chains, if strained, wear

very fast. Errors or irregularities in pitch are frequent, and the makers of patent chain blocks find it necessary to make and test the accuracy of their own chains. It is not sufficient to order a chain to any particular pitch, the wheel must be sent to the maker to ensure a fit; or, if the chain is in hand, the pattern of wheel can be fitted to it. Such chains should not be run faster than 250 feet per minute.

Patent drive chains are made with drop forged or cast steel links, and in some cases malleable cast-iron is used, but can only be depended on for light strains.

Chain wheels for flat link chains are shown in Figs. 270–72. These give very little trouble from increase of pitch, except in those cases where the links are very short. In general, the

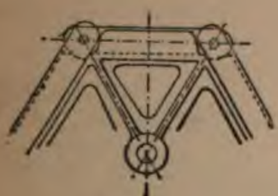


FIG. 270.


FIG. 271.


FIG. 272.

wheel sprockets wear as fast as the chain joint pins. The making and fitting of these wheels involve no difficulties, and at slow speeds they wear well. The chain is easily made from flat bar iron, the holes drilled in a jig, and hard steel pins riveted in, or, if required to be taken out, to detach the chain, ordinary headed pins and split pins (as Fig. 273) are used. Bolts and screws are not safe.

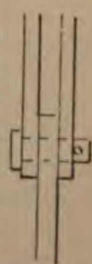


FIG. 273.

Chains to gear with ordinary spur wheels (as Fig. 261) are sometimes used, and can be obtained from makers' stocks. The large wearing surfaces exposed to the teeth cause them to wear well.

Drive chains are guaranteed by their makers to be accurate in pitch; the surfaces of the links in contact are large, both where linked together and where they gear with the wheel sprockets, so that with efficient lubrication they

give very good results. The speeds of these chains may be from 60 to 350 feet per minute.

Chain drives should always be as nearly horizontal as convenient; vertical drives are not so satisfactory. Tightening should be done by moving one shaft if possible.

The Power Transmitted by Chains.—The working strains should not exceed one-tenth of the breaking strain, and with the higher speeds this should be reduced to one-twentieth. There is not much friction in chain gear if well oiled; in this respect it compares favourably with both belt and rope gear, and it has the further advantage of a positive drive.

CHAPTER XXI.

FRICTION GEARING AND GUIDED RODS.

Friction Gearing.—The principle of driving a pair of wheels by surface contact is, at first sight, an advantageous one; as we get merely a rolling contact, there are no teeth to cut and no noise or vibration. But practice differs widely from theory here, and we find that the pressure necessary to give sufficient bite, with any form of friction gear, induces so much journal friction that, except in particular instances, this form of gear is impracticable, and therefore cannot be used in numerous cases where its smooth running would be of immense advantage.

The kinds of friction gear employed include: (1) cast-iron turned plain-faced wheels in contact; (2) cast-iron plain turned wheel in gear with a leather-faced wheel or pinion. Face gear and bevil gear of the same materials. (3) V-grooved iron wheels in gear in which the bite is obtained by wedging friction of the grooves (Fig. 274).

1. *Cast-iron Plain-faced Wheels.*—The coefficient of the friction of cast iron on cast iron being ·15, it follows that to transmit a circumferential strain of 100 lbs. (equivalent to a

$2\frac{1}{2}$-inch belt) without slipping requires $\frac{100 \times 100}{15} = 666$ lbs. pressure on the bearings, or $6\frac{2}{3}$ times the strain transmitted. This load on the shafts, supposing the bearings to be well lubricated, and taking a coefficient of friction on the journals of $\cdot 075$ will $= 666 \times \cdot 075 \times 2 = 99\cdot 9$ lbs. on each pair of bearings, or $199\cdot 8$ lbs. of shaft friction.

It is evident, therefore, that plain cast-iron pulleys in contact are extremely wasteful by friction. They are used by some hoist makers for driving power winches (see Chapter XXVI.), but such gear should not be used unless the loss of power is of little moment, and unless the possibility of oil finding its way in the working faces is improbable, as in such cases they will slip and may cause accidents.

FIG. 274.

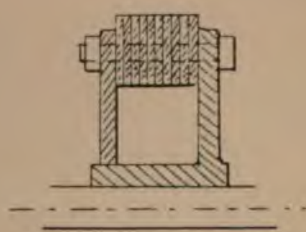


FIG. 275.

2. *Cast-iron wheels* in gear with leather faced ones are better for several reasons: leather gives a better frictional bite, the coefficient of friction of leather on iron being as high as $\cdot 5$; leather is elastic, and therefore such gear has a larger arc of actual contact than iron on iron. The leather should be fixed to the periphery of the wheel edgeways, as in Fig. 275, and bolted through, and afterwards it can be turned true on the face. Raw hide is also used instead of leather, with good wearing results. The efficiency of such gear, well set up, is much greater than that of plain iron gear.

V-*grooved friction gear* runs also very smoothly and with much less friction and pressure on the shafts than plain gear, but there is an excess of friction in the V-grooves that is

seldom sufficiently allowed for. The deeper the grooves in actual contact, and the steeper the angles of the V's, the greater the friction. It has been shown that the total friction of this form of gear is fully equal to that of plain gear, but there is less friction in the shaft journals and more friction in the peripheries. The velocities of the points A and B (Fig. 276) are not the same, there is therefore a grinding action between the surfaces in contact, which, with the pressure necessary and small area of actual contact, occasions excessive friction, and for this reason the depth of bite in the V-groove should be reduced till the surface contact and pressure approach the seizing point, as shown in section lines. Great accuracy is necessary both in the fit of the grooves and the true running of the wheels, necessitating also very good bearings. This fact alone precludes its use, except in

FIG. 276.

positions where such accuracy can be paid for. Bevil gear has been made on this principle in a few instances, but cannot be recommended, as the pressure must be applied in either direction shown by the arrows (Fig. 277) on both shafts, and cannot be applied directly in the direction of the V-grip as at A. It is therefore difficult to run these wheels satisfactorily, especially when they are not of the same diameters.

Face gear (as Fig. 278) seems to work much better, but this is perhaps due to the fact that the pinion is always of leather (Fig. 275). The bite of leather-faced gear may be increased by scoring or grooving the face of the iron wheel at right angles to the direction of motion, that is radially.

Repairs to friction gear comprise re-turning the faces of plain gear which become scored or flattened by slipping. Turning up the V-grooves of V-gear, and re-fitting leather

pinions with new leather faces. These are put together with shellac dissolved in methylated spirits, and bolted up solid, and when dry are turned true on the face. The bearings also require regular attention and wear fast, due to the excessive pressure on them. The lubricant used should be thick, and of course no lubricant can be permitted between the contact faces of the wheels—nor is any required, as there should be no slip but merely rolling contact.

Transmitting Power by Rods and Guides.—This mode of transmission has a limited field of usefulness. For continuous (reciprocating) motion by rods, mining pumping gear

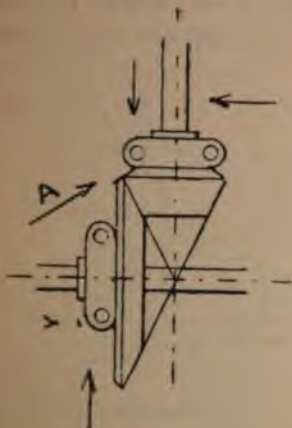


FIG. 277.

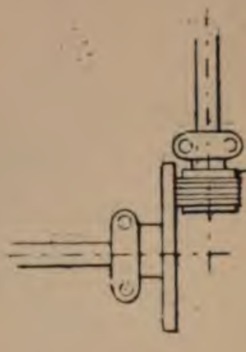


FIG. 278.

is, perhaps, the best known example; and for intermittent use railway switches and signals are well known applications of the principle. In all cases the rods are required to both pull and thrust, and therefore require sufficient stiffness for the latter or thrusting strain, which, in fact, determines the sectional area. The direction of motion may be either horizontal, inclined or vertical. In the first case they should run on well oiled guide wheels, properly grooved to receive them. In the second case, in addition to guide wheels, they require partial balancing to equalise the motion; and in the third case, of vertical working, either guide rollers or fixed guides may be used; and the entire weight of the rods must

be balanced, though in the case of mining pump rods they are only balanced partially, the weight of the rods being utilised to force up the water by pressure on the pump ram. In the case of three-throw and two-throw deep well pumps also the rods balance each other.

Rods for Power Transmission may be of any material, but, inasmuch as thrust is the greatest strain they are subject to, and lightness is desirable to reduce friction and inertia, and thus economise power, light and stiff materials are the best. Wood is much used, in lengths spliced or scarfed together and reinforced by wrought-iron plates, bands and bolts at the joints and rubbing plates at the guides. Wrought-iron tubes of light section screwed together are easily applied

FIG. 279.

FIG. 280.

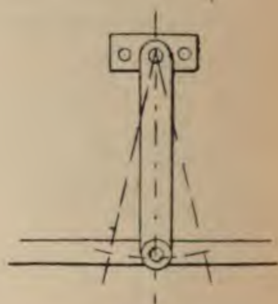


FIG. 281.

also, but care must be taken to screw up the joints very tight, as otherwise the continual thrust and pull will loosen the threads. Other wrought-iron sections adopted are L T ⊔ and H-iron. Light unwelded tube of O section can also be obtained at a very low price, but requires a socket and spigot joint as the ends cannot be screwed; L T ⊔ and H-iron are jointed by fish plates and small bolts.

Guides and Rollers.—For horizontal rods rollers are the best guides, and should be of good diameter if the rods are long and heavy, and properly grooved to suit the section of rod. If the thrust is considerable, double rollers may be necessary to prevent the rod buckling upwards, or a roller and strap (Figs. 279, 280.) For a short stroke, link suspension is

cheaper and easier to fix and to work than rollers (Fig. 281), but has a tendency always to return to the middle position.

For changing the direction of movement bell cranks are generally used, the arms of which are long enough to give the required movement with an arc of not more than 75° (Fig. 282). This may be substituted by a chain and sheave motion if the travel is considerable (Fig. 283), and in either case the rods can be carried at any angle to one another. For vertical rods plain circular or square guides are often used, but might in most cases be replaced by rollers with

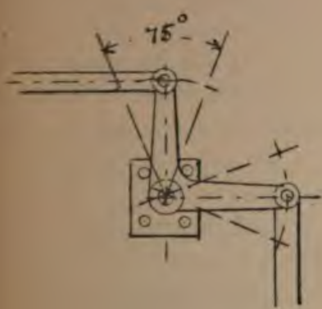


FIG. 282.

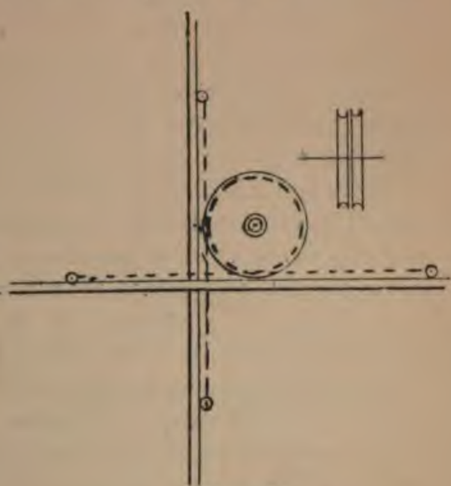


FIG. 283.

advantage, as they involve less friction and wear much longer. For outdoor work the best protection is galvanising, executed after all holes have been cut, &c.; but painting with red oxide is generally done, and of course all wearing parts soon rust and will rapidly corrode away unless protected by grease or tar, oil only is not sufficient, as it washes out in heavy rains.

The following works deal with the Transmission of Power and may be consulted: 'A Practical Treatise on Mill Gearing, &c.' by Thomas Box; 'On Designing Belt Gearing,' by E. J. Cowling Welch; 'A Treatise on Belting for the Transmission of Power,' by J. H. Cooper.

SECTION VI.—*HOISTING MACHINERY.*

CHAPTER XXII.

GENERAL PRINCIPLES.

THIS extensive class of machinery includes: (1) blocks and tackle; (2) cranes; (3) winches; (4) steam hoisting or winding engines; (5) lifts and elevators; (6) hydraulic lifts and cranes; and in one or other of its sub-divisions is to be found in every business or manufacture in the country. No other general class of machinery is so extensively used, or is so fruitful in accidents, breakdowns and repairs.

Hoisting is performed by means of ropes, chains and hydraulic pistons. The simplest hoist is a rope passed over an overhead sheave, to one end of which rope the load is attached, and to the other power is applied. This gives a speed and power of 1–1, but by altering the proportions of *speeds* of the pulling rope and the lifting rope, which is done by interposing gear, *any load can be raised by any power*, but the *speed* of load and power will be directly proportional. It is extremely difficult to thoroughly drive home this elementary fact to users of hoisting machinery, who frequently suppose that, in some way, power is gained by using a patent hoisting gear; but it cannot be too often repeated, simple as the fact is to an engineer, that instead of gaining anything, power is actually lost in friction in any and every form of hoisting gear made. Thus one man pulling a rope always with a force or power of 28 lbs. at 100 feet per minute can raise 28 lbs. at 100 feet per minute; 1 cwt. at 25 feet per minute; 10 cwts. at 2½ feet per minute; 1 ton at 1¼ feet per minute; or

10 tons at $1\frac{1}{2}$ inches per minute, and so on. This allows nothing for friction, which always increases with, and is directly proportional to, the load; so that with 28 lbs. load and a single pulley the friction would probably be 10 per cent. and the load raised, in practice, be reduced by that amount; with 10 cwts. load and gearing to reduce the speed to 1–40, the friction would be about 25 per cent., and the actual load raised, therefore, $10 - 2\frac{1}{2} = 7\frac{1}{2}$ cwts.; with a load of 1 ton the friction of the gearing will be about 33 per cent., so that the actual load raised = 20 cwts. less 33 per cent. = $13\frac{2}{3}$ cwts. It must be distinctly understood that this law applies to *every form* of hoisting machine, patent or common, the only variation being in the percentage of friction, which may be greater in one machine than another, but is nevertheless the only margin in which any saving can be effected. It follows, therefore, that any form of gearing can be so proportioned in speed that the required load, friction included, can be raised in two ways: (1) *at any speed required*; but in this case the gearing must be speeded so that the power applied will be proportioned to the speed of the load, or (2) *with any power applied*, in which case the speed of the load will be proportional to that of the power applied.

In designing or proportioning any hoisting gear, therefore, the load to be raised is first determined, then the speed required, then the power available and its speed; and from these data the speed and proportions of the gearing are easily calculated after adding sufficient for friction.

For power gear the simplest method is to calculate the H.P. of the work to be done by multiplying the load in lbs. by the speed raised in feet per minute, dividing by 33,000, and adding 50 per cent. for friction, &c.; the result is the actual H.P. of the engine.

For hand power by crank, used intermittently as in hoisting, an effort of 28 lbs. may be calculated, or, if worked by a woman, 20 lbs., and a speed of 20 revolutions per minute. For hand power by pulling a hand rope or chain, a pull of 20 lbs. for a man and 14 lbs. for a woman may be taken with a speed of 90 feet per minute.

Friction is usually a heavy item in hoisting gear, rarely falling below 15 per cent., and frequently reaching from 40 to 60 per cent. of the power applied. Epicycloidal and worm gear are the worst; friction gear nearly as bad; spur gear giving the best results; but the friction is not all in the gearing. In cage lifts a large proportion of it is due to the cage and balance weight, which, being a constant load, add a constant percentage to the gear friction, besides their own sliding friction in the guides. The bending of ropes round V and guide wheels also causes friction, and with V wheels the wedging of the rope in the groove makes it cling as it leaves the wheel, causing a retarding effort to pull it out of the groove.

Load wheel shafts should always run in roller bearings if possible, and should be of steel and of as small diameter as is consistent with ample strength; a considerable amount of friction can be got rid of in this way. Lubrication is important with all bearings, but care must be exercised that the oil does not run on to brake wheels and friction gear, as is frequently found to be the case.

Circumstances which govern the choice of Hoisting Gear.—Each type of gear has its advantages and disadvantages, and a few hints on this head may be useful. For open air hoisting some type of crane is most generally serviceable: the height of lift is seldom great, and a crane, by the sweep of its jib, can cover a circle of a diameter varying from 20 to 70 or 80 feet. Travelling cranes can be arranged to work any extent of ground. Fixed cranes can also be mounted to any elevation on a staging, and are commonly fixed to the outside walls of buildings to raise and lower goods at the loop-holes.

For inside use there are numerous types available, and the selection depends chiefly on the nature of the goods, frequency of hoists and power at command. Light, bulky or miscellaneous packages are best raised by a cage or platform lift. Packages all of one size, as flour sacks, casks, &c., can be economically handled by a chain or rope hoist with two hooks, one of which descends as the other ascends. Loose material, as corn, coal, mortar, bricks, sand, &c., can be

best carried by a bucket elevator and chain, especially if the work is continuous. Passengers require a cage hoist, protected all round and with the smoothest possible motion, quick speed and easy gradual stoppages; hydraulic power most nearly satisfies these conditions. Heavy articles of various forms, such as are found in an engineer's works, and which do not need great speed in handling, are lifted by overhead travelling cranes and by chain blocks. Swing cranes are also used for such work, but only cover a limited area and are often in the way.

CHAPTER XXIII.

BLOCKS AND TACKLE—CRANES.

Blocks and tackle are the oldest invention for multiplying power for hoisting purposes. They are, however, but little used except on shipboard, and would, no doubt, be better superseded even there by some more modern gear, the friction loss in this kind of gear being very large. With a three or four-sheave pair of blocks raising 10 cwt. the loss by friction will not be less than 70 per cent., besides which the ropes are soon destroyed by internal friction due to the frequent short bends over small sheaves; the twist of the ropes frequently causes the whole set to twist into a tangle, and the only marvel is how they have survived to the present day. Some of the best make are fitted with anti-friction rollers in the sheaves, but, though they run easier, the life of the ropes is not increased.

Chain Blocks—differential and simple—are much used and have been greatly improved, but still there is a great excess of friction in all of them. Professor Thurston gives the following as the efficiency of self-sustaining blocks: Weston's differential, 31·00 per cent.; other types, from 18·97 to 26·00 per cent. There is therefore plenty of room for improvement. As to their handiness, however, there can

be but one opinion; one man can raise any load by them, the load is held suspended and cannot run down, but is lowered in the same way as it is lifted, that is, by pulling the hand chain the opposite way. For short lifts, heavy objects, and where speed is not important they are invaluable.

In Weston's blocks the same chain is used for load and hand chain. In Moore's, Pickering's and others a separate small endless hand chain is used, and in most of the other makes worm and wheel gear is used, with a separate hand chain and wheel. The chief trouble with all of them is the wear and stretching of the lifting chain. They are frequently used for loads greatly in excess of their calculated working strength, and become strained and worn. Dirt, rough handling and lack of proper oiling are fruitful sources of deterioration; one troublesome difficulty that often occurs is, that when thrown down and afterwards rehung the chain becomes twisted, this is, perhaps, not discovered till it jams or slips, and then takes an inexperienced man a long time to straighten up. Some of them have chain guides intended to prevent this, but they are only partially successful. What is wanted to improve these chain blocks is either a flat link pitch chain or steel wire rope for hoisting, and soft hemp rope for the hand, with some means of reducing the excessive friction. Suspending frames are often of malleable cast iron, but this material is not safe for tensile strains, and forgings ought to be used.

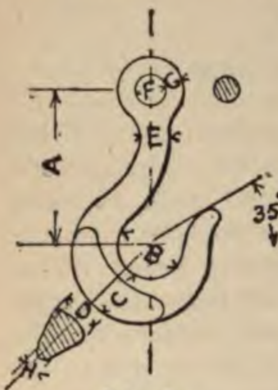


FIG. 284.

Cranes: Fixed.—All hoisting gear is subject to great stresses and sometimes sudden strains, and this is particularly the case with cranes, especially if worked with chains. They are liable to ride or overlap in coiling on the barrel, and slip back into their proper lap, causing a violent jerk. Hoisting barrels should, therefore, be cast with a spiral groove to receive and coil the chain properly. Care should be taken

DIMENSIONS OF CRANE HOOKS (Fig. 284).

Safe Load.	A	B	C	D	E	F	G	H
tons.								
	$3\frac{13}{16}$	$2\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	1	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{3}{16}$
$\frac{3}{4}$	$4\frac{1}{8}$	$2\frac{1}{2}$	$1\frac{7}{16}$	$1\frac{1}{4}$	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{1}{4}$
$1\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{11}{16}$	$1\frac{5}{8}$	$1\frac{5}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{5}{16}$
$1\frac{1}{2}$	$4\frac{7}{8}$	$2\frac{13}{16}$	$1\frac{3}{4}$	$1\frac{5}{16}$	$1\frac{3}{16}$	1	$\frac{7}{8}$	$\frac{3}{8}$
2	$5\frac{1}{4}$	3	2	$1\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{1}{16}$	$\frac{15}{16}$	$\frac{7}{16}$
3	$5\frac{5}{8}$	$3\frac{1}{8}$	$2\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{5}{16}$	$1\frac{1}{8}$	1	$\frac{1}{2}$
4	$5\frac{15}{16}$	$3\frac{5}{16}$	$2\frac{5}{16}$	$1\frac{7}{16}$	$1\frac{3}{8}$	$1\frac{3}{16}$	1	$\frac{9}{16}$
5	$6\frac{5}{16}$	$3\frac{7}{16}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{7}{16}$	$1\frac{1}{4}$	$1\frac{1}{16}$	$\frac{5}{8}$
6	$6\frac{21}{32}$	$3\frac{5}{8}$	$2\frac{11}{16}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$\frac{11}{16}$
8	$7\frac{3}{8}$	$3\frac{15}{16}$	3	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{11}{16}$
10	$8\frac{1}{8}$	$4\frac{1}{4}$	$3\frac{5}{16}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{4}$
12	$8\frac{27}{32}$	$4\frac{9}{16}$	$3\frac{5}{8}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{13}{16}$	$1\frac{7}{16}$	$\frac{3}{4}$
15	$9\frac{9}{16}$	$4\frac{7}{8}$	$3\frac{7}{8}$	2	2	$1\frac{15}{16}$	$1\frac{9}{16}$	$\frac{13}{16}$
18	$10\frac{1}{4}$	$5\frac{3}{16}$	$4\frac{3}{16}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$1\frac{5}{8}$	$\frac{13}{16}$
21	11	$5\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{7}{8}$

also to take out any twist from the chain between the jib head sheave and the barrel; and to make this effective all sheaves should be grooved, as Fig. 268 (without the sprocket teeth), and plain round grooves avoided, as these allow a twisted chain to travel over them.

Brake wheels should always be upon the barrel or load shaft. It is not safe to allow the load to act on the brake wheel *through spur gearing*, and for the same reason ratchet wheels ought always to be on the load shaft. It is remarkable that these rules are not by any means invariably carried out, and that, in fact, a good deal of rule-of-thumb practice still exists among makers of hoisting machinery. Crank handles should always have loose ferrules for the hand, and should be firmly fixed to the shaft; accidents frequently happen from the handle slipping off when raising a load. In lowering by brake the gear should be arranged so that the handle and intermediate gear do not revolve, but only the barrel and brake wheel. Serious injuries have been caused by the

handles revolving rapidly and in some cases flying off. The brake should be powerful enough to hold the heaviest load, even when the wheel is oily or wet. Guards should always be fixed over all guide sheaves to prevent the chain slipping off, which may easily happen when pulling a little out of line. The strength of teeth, pitch and speed of the gearing are calculated by the usual rules, for which see text books.

Barrels or drums should be as large in diameter as possible for the size of rope or chain used. The sizes given in the table (p. 284) are those ordinarily made. Wire ropes, however, require larger barrels, the diameters of which should not be less than fifteen times the diameter of the rope (see p. 262) and when ordering wire ropes the diameter of the barrel should be given. Ropes can be made more or less flexible by using thin or thick wire, and wire or hemp cores; but frequent bending distresses a wire rope more than a hempen one.

Chains should have a factor of safety of ten, and be tested. They require also to be annealed and retested every three years to maintain their quality, as the iron becomes crystalline with hard work (see p. 267).

Leather is the best brake lining, but wood and iron are also used. The strap brake is preferable to a block or shoe, giving a better grip round the wheel, but two blocks which grip the wheel between them form a good brake (see p. 288).

The construction of jib, framing, &c., has of late years been much improved; crane posts are not much used now, the thrust and pull of the jib being taken by rollers and a centre bolt, but a good deal may yet be effected in saving of friction in the bearings, &c.; wrought iron or steel should be preferred to all other materials in the construction of crane framing of all kinds, as they are not much affected by jar and vibration, and a much lighter framing can be made from ordinary merchant bars with sufficient stiffness and elasticity. The old type, heavy cast-iron structure still exists, but is rarely manufactured now.

Sketches of the various types of cranes will be found in the 'Engineer's Sketch Book,' pages 47 to 55.

Steam cranes include, besides the winding gear and

framing, an engine and boiler. These are usually fixed so as to assist to balance the crane jib; but a fixed crane may be driven from a shaft, if necessary, by bevil gear and a vertical shaft in the centre of the crane pivot. The engine and boiler need no special mention here; they are of the vertical type with *two cylinders* and reversing gear, and the motions are taken direct from the crank shaft with clutches to throw in and out of gear the lifting, slewing and jib raising motions, and in some cases a travelling motion also. Jaw clutches are generally used, operated by hand levers. The slide valve gear should be carefully adjusted in these engines, so that they can be run very slowly if needed; no fly-wheel being used they are apt to run very unevenly except at full speed. It is always worth the expense to have a roof over the crane, when out of doors, to protect the mechanism and boiler from the weather; also to have the boiler well lagged. For details of engines and boilers of this type see p. 90.

The wear and tear of this class of cranes is chiefly confined to the engine details and the lifting chain; but the clutches and toothed gearing wear out in time, and need renewing. Toothed pinions ought to be shrouded, and may be of steel. All keys should be well secured; the quick running shafts should have renewable gun-metal or phosphor bronze bearings, but the slower shafts ordinarily run in solid cast-iron or capped bearings. Cheapness and competition are responsible for a good many defects found in crane details.

CHAPTER XXIV.

WINCHES AND HOISTING ENGINES.

Winches are made in several forms for special purposes, hand power winches or crabs, steam winches for ships' decks and for general hoisting purposes, small winches for fixing to walls, posts, &c.

For hand power the common "crab" winch is very largely

used. It consists of two A frames bolted apart by distance rods, and fitted with a barrel, chain or rope, brake wheel, ratchet wheel and pawl, brake strap and lever, crank handles and shaft, pinion and spur wheel, and, if double geared, a second motion shaft, spur wheel and pinion, and sliding clutch to throw it in or out of gear. It is easily moved about, easily fixed anywhere, cheap, and very often nasty. The prices preclude a good job as a rule. Many of them have neither boring or turning on them, being put together of plain castings and bar iron.

The following table gives the principal dimensions of crab gears for various loads, as ordinarily manufactured.

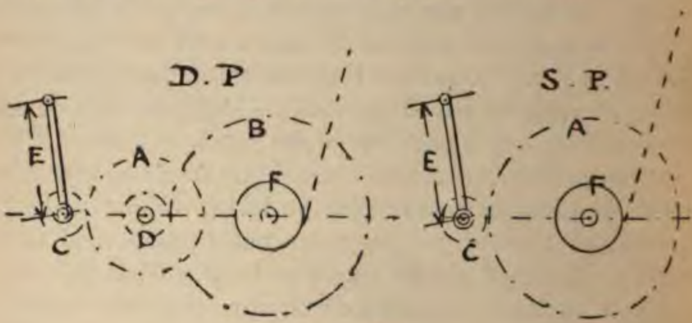


FIG. 285.

Wrought-iron frames are now used for the best winches hand and steam power, and are lighter and stronger in every way than cast iron.

Steam winches sometimes have an independent boiler, and thus become hoisting engines, the boiler generally being fixed on the same base as the winch; but more frequently they take steam from a neighbouring boiler. They are fitted with two cylinders, cranks at right angles, no fly-wheel, link reversing gear, brake wheel, strap and foot lever, and single or double purchase gearing with sliding clutches for throwing them in and out of gear. Large numbers of this type are used on ships' decks (see p. 145), exposed to all weathers and bad treatment generally, which, coupled with the fact that competition in prices badly handicaps them from the outset.

ere is nothing surprising in the fact that they are rarely in ›od order, are noisy beyond description and hardly safe to e in many cases. The valve gear wears out rapidly. It ould be a great advantage to introduce a more modern form reversing gear with fewer joints. The slide valves work so regularly that it is impossible to run them except at full eed, and with excessive loss of steam. The gearing and afts would usually outlast three or four engines driving em. The men in charge of them usually are not echanics, and therefore do not attend properly to the brication, setting up bearings and brasses and so on, the sult being general looseness and rapid wear.

TABLE OF CRAB AND CRANE GEARING (Fig. 285).

gle or ouble rchase.	Pitch.	Wheels. A and B.		Pinions C and D.		Width on Face.	Rad. of Handle E.	Brake Wheel.	To lift direct from Barrel.	Barrel F.	
		Dia.	Teeth.	Dia.	Teeth.			Dia. Face.		Dia.	Length.
	in.	in.		in.		in.	in.	in. in.	tons.	in.	in.
. P.	1	20	64	4½	14	2	12	12 × 2¼	7 cwt.	5	11
. P.	1	24⅛	76	4¼	13	2¼	13½	12¾ × 2½	·66	5	15
. P.	1 1/16	25¾	76	4¼	13	2⅝	13½	15⅝ × 2¾	1·0	6½	20
. P.	1⅛	27⅜	76	5	14	2¾	13½	18 × 3	1·5	7¼	22
. P.	1	8⅞	28	4¼	13	2¼	14	12¾ × 2⅝	·66	5	15
	1	24⅛	76	4¼	13	2¼					
. P.	1	8⅞	28	4¼	13	2½	14	12¾ × 2⅝	·825	5½	18
	1	24⅛	76	4¼	13	2½					
. P.	1 1/16	10⅝	31	4¼	13	2⅝	14	15⅝ × 2¾	1	6½	20¼
	1 1/16	25¾	76	4¼	13	2⅝					
. P.	1⅛	12¼	34	5⅛	14	2¾	14½	18 × 3	1·5	7¼	22
	1⅛	27⅜	76	5⅛	14	2¾					
. P.	1⅛	12¼	34	5⅛	14	3¼	15	18 × 3	2	7¼	25
	1⅛	30¼	84	5⅛	14	3¼					
. P.	1⅛	14⅜	40	5⅛	14	3½	15½	20 × 3	2·5	7¼	25
	1⅛	33⅛	92	5⅛	14	3½					
. P.	1¼	15⅜	38	5¾	14	3½	16	24½ × 3	3	8½	26
	1¼	36⅛	90	5¾	14	3½					
. P.	1⅜	18¾	38	5⅞	12	3¾	16⅝	26 × 3½	4	10	28¼
	1⅜	42	88	5⅞	12	3¾					

The best test of a hoisting engine is to run it very slowly with a load on. If it passes this ordeal there is not much the matter with it.

Shafts and hand cranks are often provided so that the winch may be worked by hand power if the steam is off from any cause, and are sometimes a great convenience.

Several forms of bracket or wall crabs are now made for light uses, and are fitted with either a self-sustaining brake motion, worm and wheel gear, or ordinary ratchet and pawl to sustain the load; lowering being performed by reversing the motion of the handle.

In fixing any of these winches it is important to place them square with the snatch block or sheave A (Fig. 286), over which the rope or chain passes, and in order that the rope or chain may coil evenly on the barrel without riding, the winch should be a little out of centre towards the end of the barrel on which the rope commences to coil, as shown. The sheave must also be fixed at least 12 or 15 feet away, in order to give a fair lead to the rope. Wire ropes will only coil closely on a barrel if coiled with the twist, as shown in Fig. 287; if the coil is commenced at the other end of the barrel (with a right hand twist), the rope will coil with open spaces, and travel quickly across the barrel; but in well-designed gears the barrel is grooved spirally to ensure close coiling.

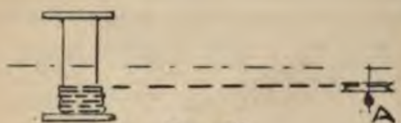


FIG. 286.

Steam Hoisting Engines. Winding Engines.—These comprise engines employed in raising ores, &c. from mines, raising materials to blast furnaces, working inclines, rope railways, &c., and are higher developments of the steam winch, but, as a class, are infinitely better built and designed, cost is less considered, and in many cases the workmanship and finish are all that can be desired. They are controlled by careful mechanics, and therefore do not suffer from neglect or exposure. In many cases they are of considerable power, with double cylinders, and well installed with every modern

iance to ensure safety and regular working. A feature inding engines is the absence of condensers and of com- ading; this is necessitated by the need of great handiness opping and starting. High pressure steam with automatic off is therefore used, and a special form of valve gear is etimes employed to enable the engine to be pulled up at point in the stroke. Ordinarily this is effected by a very erful brake gear, strong enough, in fact, to stop the engine full steam on, in less than half a stroke. The efficiency he brake is a most vital point in all winding engines. re are three styles of brake adopted: (1) an entire strap . 288), generally in two parts, hinged to a bracket to

FIG. 287.

FIG. 288.

end the weight of the strap when off; (2) a partial strap ally fixed *under* the brake ring (Fig. 289), so as to tend to it when thrown on; (3) double blocks fixed vertically at osite sides of the brake ring (Fig. 290), hinged at their om ends to strong brackets in the foundation, and pulled ether at the upper ends by a toggle lever gear, so as to the brake ring between them. In large engines this is formed by a steam cylinder operated by an ordinary slide e from a hand lever; but a foot lever is always fixed in ition by which the brake can be thrown on at any time. ge engines use Cornish equilibrium valves, opened and ed by cams. Escape valves and pipes of large size are provided to the cylinder covers to release condensed

water from the cylinders, and in some cases a lever and gear are provided so that they can all be opened at once by the engineer when starting his engine.

Winding drums for great depths require a compensating arrangement to equalise the strain on the engine; thus with an engine hauling from 600 yards depth, with loads of 4 tons, the rope will weigh 4 or 5 tons, so that the pull will vary from 4 to 8 or 9 tons, to which must be added the overbalance of the descending rope, say 4 tons more; so that, starting with 8 tons load, the journey is finished with 4 tons, balanced by 4 tons of descending rope, or 0. Formerly flat compound ropes were universally used, and were compensated by coiling

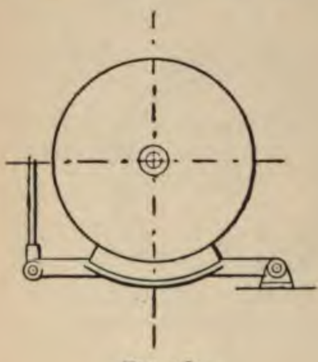


FIG. 289.

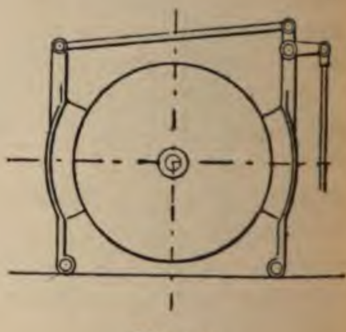


FIG. 290.

the rope on itself in a narrow deep grooved drum. The latest method is a drum of a conical or fuzee form, using round ropes, the coil commencing on a small radius and finishing on the largest. Another method of compensating is the employment of a balance chain a little longer than the height of lift; one end of the chain is fixed to the under side of each cage, and the weight of the chain per foot run is as near to that of the lifting rope as possible. This has the effect of neutralising the variation of load due to the rope in all positions. There is of course no strain on the chain, which is simply so much dead weight. This plan admits of the use of parallel drums.

The old type of winding engines—many of which are still

running—was a beam engine—generally a single one—coupled direct to the drum shaft, and fruitful in over-winding and back-winding accidents. Such an engine must always be stopped and started with the crank about half stroke, or it will dead centre. Double engines with the cranks at right angles cannot give trouble in this way. Very careful handling of the starting lever and brake were necessary with these old engines. Gearing down has also been tried with small high speed engines, but sufficient speed cannot be attained in this way for mining purposes ; but this kind of engine is still much used for general hauling purposes, for working inclines, blast furnace hoists and goods lifts. High pressure and moderate expansion by ordinary slide or piston valves are employed in conjunction with powerful brakes and plain drums. Either single or double ropes and cages may be used, the latter being most economical and rapid.

In the details of construction of winding engines there is not much that differs from general types of horizontal engines further than the points already noted. The drums, of course, serve the purpose of fly-wheels, though with well adjusted valves and duplicate engines no fly-wheel is needed. Some engines are fitted with clutches and one loose drum, so that either one or two ropes can be run. In other cases an engine has to wind from two or more different levels, and the lengths of the ropes (when two are used) altered daily. This is effected, without detaching the ropes, by running the drums separately to the level required and then coupling them up again.

A pit gauge is fixed facing the engineer so that he can see at all times the motion of the cages reproduced on a reduced vertical scale. A screw and travelling nut and pointer is generally used for this, or a string and weight, which winds on the crank shaft, or a small drum driven from it. Automatic steam cut-off gear is also used to close the throttle valve when the cage reaches the pit mouth.

The piston speeds are often very high ; 600 and 700 feet per minute is now a usual figure with large engines, the cages travelling at speeds of 3000 to 4000 feet per minute ; but with smaller engines for inclines, &c., the speeds are seldom more

than 200 or 300 feet per minute for the cage, and 120 feet per minute for the pistons.

For the higher speeds very large steam passages and valves are necessary. The reversing gear must be easily handled by one man, and all the levers placed within easy range, so that the driver can handle them readily while facing his engine and watching his guages and signals.

Wear and tear in winding engines is usually less than in mill engines of equal power. Reversing engines, however, always give more trouble in the valve gear than those that run in one direction only. The ropes seldom last more than one to two years, but the cylinders, pistons, rings, steam valves, brasses, &c. are long lived, and should run for fifteen years with very little attention.

For the general repairs of such details, see pp. 51–86.

In the winding portion of these engines there is little to note as to repairs. Wood lagging on drums sometimes requires renewing, also wood linings to brakes and break blocks, new centre pins and bolts.

For notes on cages, guides and safety gear, see pp. 293, 317 and 320.

CHAPTER XXV.

LIFTS. HAND-POWER.

Lifts. Elevators.—Under this heading is included all types of cage and platform lifts, passenger lifts, continuous lifts, and bucket and other chain elevators.

The use of lifts is greatly extending in this country. In America, where they are all classed as elevators, they are still more largely used, but with perhaps less variety in construction. The convenience and handiness of lifts enables upper floors—hitherto unapproachable—to become as useful as, and often more desirable than lower ones. In America the lift has produced a type of enormous and very high build-

ngs, impossible without it, and the tendency is to add to heir more extensive use in all sorts of business and public uildings, where they become of far greater importance than he staircase.

Safety, speed, and steady smooth motion both up and lown are the chief essentials, and many of the modern nstallations very fairly embody these qualifications.

They apply to every purpose where anything has to be conveyed up or down (excepting liquids, which can be conveyed by pipe or by pumps), and may be conveniently dealt with under three heads. (1) Hand-power lifts. (2) Power ifts. (3) Hydraulic lifts.

1. *Hand-power lifts* vary in size from the small office or book lift, chop house or dinner lift, hotel, coal or luggage lift, warehouse or goods lift, carriage or furniture lift, to the invalid or hospital lift; and the weights raised from 14 lbs. to 1 ton. n almost every case the gear is fixed overhead and the cage alanced by a weight or another cage, the power being applied y an endless hand rope. In a few cases a winch-handle is sed with a barrel for coiling the rope, but this method is not o reliable, as it involves the use of ratchets and pawls. The ear as ordinarily constructed is simply a winch, geared or ngeared, and worked by a V-wheel and endless rope instead f a crank handle. The brake is a plain pulley with a jointed trap encircling it, a lever and hand-rope to pull it into gear nd a balance weight to return it out of gear. Cleats are sed to secure the rope when the cage is stationary; or in ome cases a pawl or catch, both methods being insecure nd dangerous from careless use by unskilled servants.

The faults of this construction of gearing are these:—The rame, bearings and other parts are usually detached pieces, ndependently bolted to the wooden cross bearers, and liable o get loose and out of line by shrinking and twisting of the vood. The gearing is often so boxed up that it rarely gets iled, self-oiling appliances being seldom applied. There is ften an excess of friction from bad design, bad fixing, ropes ut of line, brake strap never entirely off, cage jamming in its uides, or balance weight a tight fit, and other causes. The

brake is often unsatisfactory, the joint pins work out or become so loose and worn as to have too much play to give any grip to the brake. The strap may become oily and slip. In a few cases the cage rope slips on the V-wheel by bottoming in the groove, in which case a larger rope must be substituted or the V-groove turned to a sharper angle. The brake wheel ought always to be fixed upon the load shaft (see p. 281), and the strap hinged so that it is quite free from the wheel when off.

Too sharp a groove in the V-wheel causes it to wedge the rope so hard that it requires force to release it as the

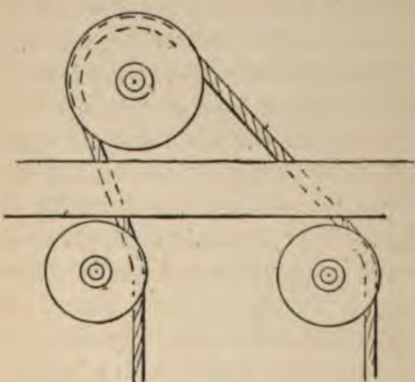


FIG. 291.

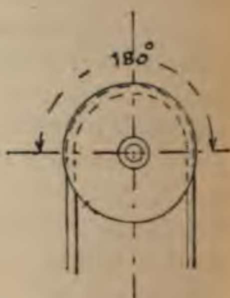


FIG. 292.

wheel revolves, absorbing considerable power and causing the rope to wear rapidly. The guide wheels are generally too small in diameter. It must be remembered that a short bend, even for a small angle (Fig. 291), is nearly as bad as if carried all round, as Fig. 292, or 180°, as far as straining the rope is concerned. The grooves in all the wheels ought to be of a good depth and perfectly smooth, to ensure good wear and prevent the ropes getting off the wheels.

Cages and guides are usually of wood; the cages are best when framed and panelled throughout; this is the strongest and lightest construction. Buffers, springs or felt pads should be used for the cage to rest upon or stop against, both at top

and bottom. The suspension should always be from a wrought-iron strap which passes down both sides of the cage and is turned under it and bolted. This is the only safe method. Eye bolts, crossbars, &c., are all liable to pull off with any sudden strain. The cage may be overbalanced by a weight fitted with loose sections for adjustment, but with ordinary hand-braked gearing the overbalance must not be heavy enough to run the cage up empty, or it may strike the top and smash itself Guides are of wood: white, red or yellow pine, or pitch pine. The kind of wood is of no great importance, but it must be straight grained, free from large knots and liability to twist or warp after fixing, as this will certainly spoil the free motion of the cage and even jam it entirely in places.

Black lead is the best lubricant; ordinary iron or brass (smooth) guide plates or runners are generally used—rollers run easier but are almost invariably noisy. Hard rubber rollers on turned pins answer very well, however, but require renewing when the hole gets too large, and *must not be oiled.* Black lead may be used on them, however, with advantage. Wood or metal rollers will do in the same way if bushed with leather or hard rubber.

Large cages should be avoided as much as possible. A large cage requires a large balance weight, adding considerably to the dead load and normal friction.

Self-sustaining hand lifts are now much used in place of the ordinary winch gear. These are not liable to run down, have an automatic brake motion, so that there is no brake rope to handle or get out of order, and are much safer to use by ordinary unskilled attendants. The brake friction is obtained in some types by friction discs or plates, forced together by cams or bolts; in others an ordinary brake wheel is used. The latter is to be preferred. Discs are liable to become oily and slip. The adjustment of the cam or bolt grip also, is sometimes a very fine one and easily disorganised. The brake gear is usually enclosed in a box, an objectionable plan, as it is impossible to see how it is working. There is a popular and well founded dislike to all boxed up mechanism.

One serious fault that has greatly hindered the more extensive use of self-sustaining lifts is that in some of them the brake

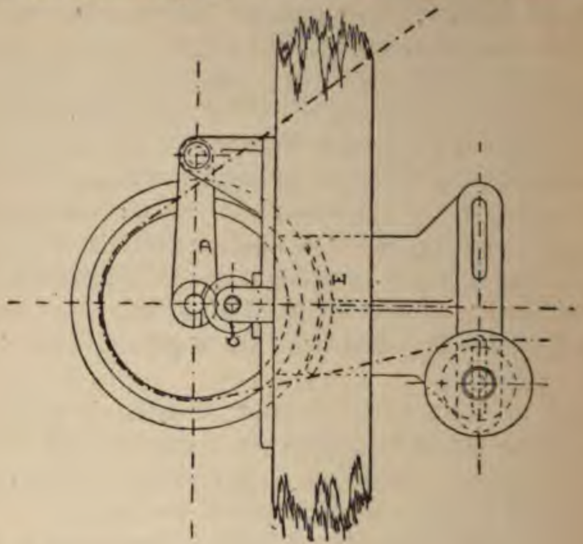


FIG. 294.

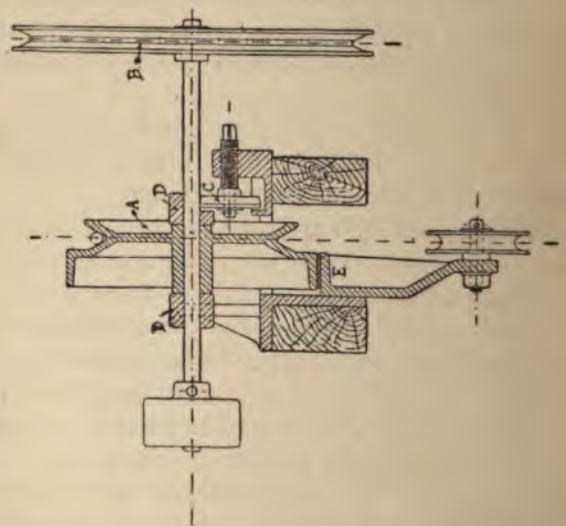


FIG. 293.

is so contrived that it is never really off entirely, and there is a continual friction from it which reduces the efficiency of the gear and causes the lift to work heavily. Pawl and ratchet

motions are objectionable in all lift gears and ought to be avoided. Most self-sustaining lifts will only sustain one way, and cannot, therefore, be used with two cages, nor with an excessive overbalance, as the brake would not act on the ascent journey. A further fault with some gears is that with a loaded cage descending by pulling the hand rope, the cage overruns the hand rope and is checked at every pull, so that it descends with a jerky motion, which is unpleasant and unsafe. There is no remedy for this but fine adjustment, or failing this, another type of gearing.

One of the latest types of this kind of gearing for hand power lifts (Barber's patent) is shown in the accompanying Figs. 293, 294. In this plan the shaft itself acts as a lever of the first order, having a slight vertical rocking motion in its bearings D D. It rocks on the edge of a plain friction roller C, which is adjustable so as to vary the leverage. When the hand rope is pulled the shaft lifts the brake wheel just free from its brake block E fixed below it, so that the entire gear is then free to revolve and the weight is then carried on the friction roller; but when the hand rope is released the loaded cage pulls down the shaft again and the brake wheel rests in the segment brake and so prevents the load running down. The cheese weight on the back end of the shaft is required to balance the hand rope and wheel, which would otherwise act in relief of the brake. In this way, therefore, the entire load of cage, load and balance weight act on the brake when standing.

Hand ropes, when new, require to be untwisted a good deal, or they will kink when spliced up; it is best to stretch them for a day or two first. Soft hemp, Italian flax, or cotton are the best materials for hand ropes, and tarred hemp for cage ropes. Manilla is often used and is rather stronger, but creaks a great deal when passing the wheels. For the larger lifts steel wire ropes in duplicate are best, with sheaves grooved as Fig. 295, and for passenger lifts and invalid or hospital lifts three or even four ropes may be used. The end attachments are very important. Figs. 297–300 show various plans in use besides the ordinary seaman's splice. In Figs.

FIG. 295.

296, 297 and 298, clips and bolts of wrought-iron or steel grip the ends of the rope together and are easily fixed, besides giving a good bite and means of taking up the rope if it stretches. Figs. 299 and 300 are for wire ropes. The end

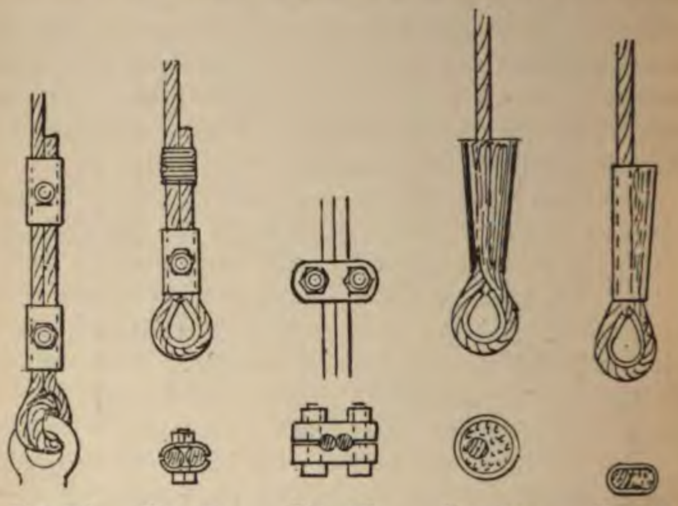


FIG. 296. FIG. 297. FIG. 298. FIG. 299. FIG. 300.

wires are turned back on the rope to thicken the end, and then forced into the tapered ferrule, which is then filled with melted type metal or lead. Steel wire ropes do not stretch much unless very long, but some allowance is made for taking up either in the rope end attachment or by a long bolt eye, to which it is secured instead of a shackle or lug.

CHAPTER XXVI.

POWER LIFTS.

POWER lifts include all hoisting gears used inside buildings, which are driven by power either from an engine direct or from shafting. In these lifts the gears are seldom fixed overhead, but either on a floor or suspended below a ceiling

or floor, where they can be conveniently driven. The methods of driving and balancing are outlined in Figs. 301 to 305. When worked without a cage the gear becomes practically a power winch (see p. 285), and is most economically worked with two ropes, one of which ascends as the other descends, otherwise a single rope and hook are used, as in a crane, with a ball weight to pull down the empty hook. Fig. 301 shows the simplest construction. The cage is connected by a rope or ropes to the balance weight, and the hauling or winding rope is attached to the foot of the

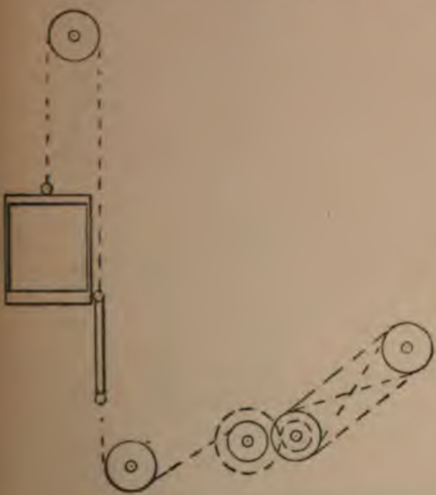


FIG. 301.

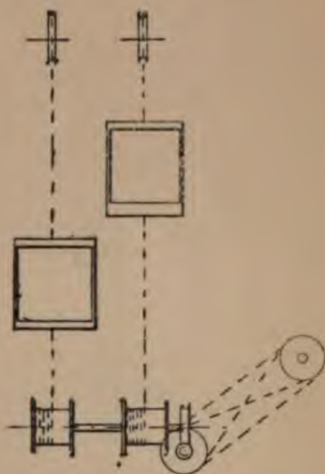


FIG. 302.

balance weight, and descends, passing round a sheave fixed below the weight guides, to the winch. Fig. 302 is a double cage arrangement, worked by two ropes and two barrels, no balance weight being required. It is usual in this arrangement to use a third rope to connect to the tops of both cages, passing over a pulley at the top of the lift (not shown in the figure). Fig. 303 is a common method of working in which a separate rope is used for the balance weight; this rope may, of course, run to any side of the lift. Fig. 304 is the method adopted without a winding drum. A V-wheel is fixed on the winch shaft, and the rope passes from the cage, over an

overhead pulley, down the shaft, under the V-wheel, then up the shaft, over another overhead pulley, and down to the balance weight. An additional rope may run over another overhead pulley direct to the balance weight, but must be kept very slack, as a safety rope, or it will destroy the tension of the winding rope in the V-wheel.

Fig. 305 is an arrangement for driving an ordinary self-sustaining hand-power lift by two pairs of grip wheels driven from any convenient shaft. In this plan the starting gear

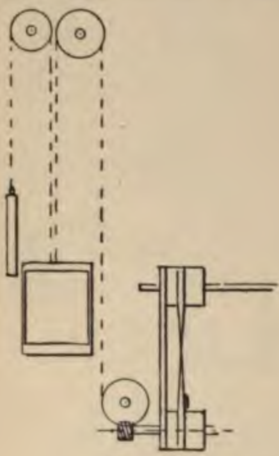


FIG. 303.

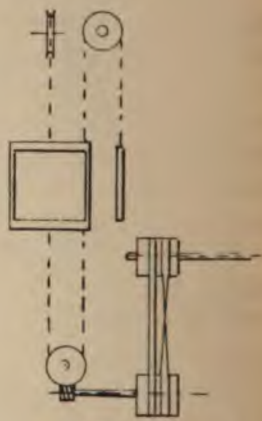


FIG. 304.

throws either pair of gripping wheels into bite with the rope, either to lift or lower, and when both pairs are out of gear the cage stops.

The starting and stopping motion consists of an endless hand rope, running the entire height of the lift well, over a sheave at top and bottom, and attached by one part to the starting lever of the winch which shifts the belts. Two belts are used, an open one and a crossed one, and three pulleys, driven from a wide drum on the countershaft; the lever must be balanced. Worm gear is most commonly employed, but has some drawbacks; these are, (1) the high speed of the worm shaft and belts; (2) the great amount of friction in the worm worm wheel and thrust bearing; (3) the worm shaft

must be fitted with a brake or it will revolve on the down journey of a loaded cage, when the belts are on the loose pulleys, and cause the cage to continue to descend. This brake is worked generally by cam lifters on the belt fork bar, which lift the loaded brake out of action when one of the belts is on the fast pulley, and let it on again when the belts are both on the loose pulleys.

Spur gear is driven direct by two or more pairs of wheels to reduce speed on to the drum shaft. With this gear there is much less friction than with worm gear; the friction of the two types of lifts may be averaged at, worm gear 50 per cent., spur gear 35 per cent. of the power applied. With spur gear, the starting and stopping motion consists of a lever which shifts the two belts (open and crossed as before) and also applies a brake, by cam lifters, on the belt fork bar, as described above; but the brake is a heavier one in this case, as it must sustain the entire load.

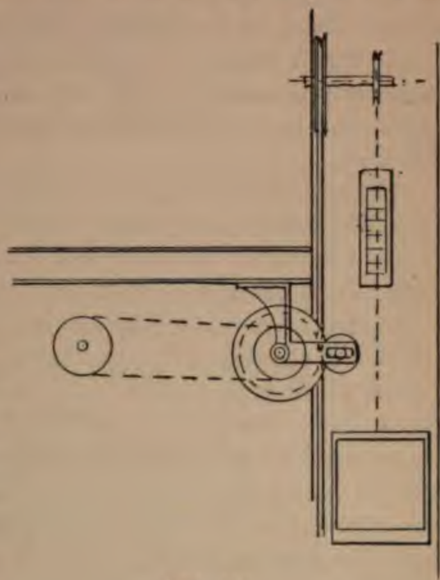


FIG. 305.

Hand starting ropes should have a travel of from 1 foot to 3 feet, according to the speed of the lift. More travel is needed with high speeds, to bring the cage to rest without shock, and the starting lever is arranged accordingly.

Electric motors are now coming into use for working hoists and power lifts generally, and where a skilled attendant is kept will give satisfaction, especially when the current can be obtained by meter from a public supply.

When a power lift is driven by a steam engine or gas engine, it is usual to fix the belt drum on the engine shaft and drive the belts direct to the hoisting gear fast and loose pulleys; this allows the engine to run continuously, and the governor cuts off the steam or gas to suit the demand made on the engine by the lift. This is better than an engine driving direct on the hoisting gear, as in the ordinary steam winch, which must be stopped and started at every journey. A gas engine will not work thus at all, and a steam engine would give a deal of trouble to start effectively from a hand pull rope.

The wear and tear of these lifts is considerable; we find that the worms and wheels wear very rapidly, especially if the lubrication is inefficient (see p. 250); gearing is longer lived, but worm shaft and first motion bearings wear rapidly; the belts do not last long, the continual shifting, high speed, and slipping when passing from fast to loose pulleys, as well as the high tension, soon destroy them. The drums, drum shafts, starting gear and brake wear fairly well; the brake block or strap may require renewal at long intervals, but the other parts need give no trouble. Special lubricators are required to effectually oil the loose pulleys, which are generally running all day. It is necessary that both the power gear and the overhead sheaves should have a rigid fixing, as a springy one causes a jerking motion to the cage from each tooth of the gearing passing in and out of gear. In balancing the cages in power lifts, the weight must be *less* than that of the cage, leaving sufficient unbalanced weight in the cage to enable it to descend from the top with certainty in those lifts where a separate rope is used for the balance weight, or the lifting rope is attached to the foot of the balance weight, as Figs. 301, 303 and 304; otherwise, if it sticks when started down, the rope goes on unwinding from the drum, and the cage may then start and fall rapidly until it overtakes the rope, and thus cause an accident. It is important, also, to allow plenty of width in the belt pulleys and a little dead travel in the centre, so that one belt does not go on until the other is well off; neglect of

this detail causes the starting to be too nice, and the rope may be easily pulled too far, causing the cage to start off immediately the opposite way instead of stopping—a fruitful cause of accidents. It is essential that every moving part be perfectly free—cage, sheaves, ropes, balance weight and gearing—to prevent possible sticking and avoid friction.

Power gear to Hand Lifts.—Any kind of self-sustaining hand power lift may be driven from a shaft by grip pulleys which bite the hand rope at either side to lift or lower, Fig. 305, p. 299. In this gear the starting rope is attached to a cam bar, which, by revolving opposite ways, presses one or other of the two grip wheels into gear to bite the rope.

The brake is, of course, automatic in the overhead self-sustaining gear, and the lift may be worked by hand at any time by the hand rope, whether the engine is running or not.

CHAPTER XXVII.

CONTINUOUS LIFTS, TRAVELLING STAGES, ETC.

THERE are now several types of these which have a limited field of service: (1) the multiple cage or platform passenger lift; (2) the multiple box parcel lift; (3) barrel and goods lifts; (4) travelling stages.

Passenger lifts of this class have a number of small cages—each to hold one or two passengers. The cages are attached by centres and bearings to one or two pitched link chains running over sprocket wheels at top and bottom. Guides are provided by which the cages are led and maintained vertical in all positions. The advantages claimed are: (1) that there is no waiting for the cage, as one or other cage is passing every floor, both up and down, every few seconds; (2) no attendant is required; each person steps on and off without assistance; (3) safety, as far as accidental falling of the cage or of persons down the well hole are concerned.

The objections are: (1) slow speed—against this must, however, be set the fact that there is no waiting; (2) noisy working, inseparable from chains, sprocket wheels, and a system of detached guides; (3) considerable wear and tear and repairs. Accidents from false steps, &c. are provided against by hinging portions of the floors of landings and cages, and a stopping rope usually runs down the lift well within easy reach of passengers at every floor. These lifts, however, are rarely used by timid or nervous persons or ladies, in fact they are going out of use in favour of quick speed hydraulic lifts.

The wear and tear of chain pins, centres and guides are considerable. The chains stretch by wear of pins and sprocket wheels, necessitating adjustment of the lower wheel, for which reason the lift must be driven at the top, a point which is not always convenient. A good deal of oil is required, and attention to the many working parts. The whole thing, in fact, lacks simplicity.

Smaller continuous lifts for parcels are useful in business and manufacturing premises, where a continuous passage of articles takes place from floor to floor. Post offices, large tailoring factories, laundries, &c., find them of service; the general construction is similar to those last described, but the cages are small, and sometimes mere shelves or trays. Noise is of little consequence, and their usual slow speed fast enough for such services. Hard steel pins must be used for all chains, and the ends of the links may be case hardened, or, if of steel, tempered; sprocket wheels may be fitted with leather round the rims to obviate noise from the chains working round them.

Barrel lifts are simply a pair of endless drive chains running continuously over sprocket wheels at top and bottom, and intermediate grooved guides. On the chains are secured at intervals curved horns in pairs, upon which the barrels are rolled and carried to the floor above, where they roll off as the horns pass round the sprocket wheels. The important points in these lifts are attention to the chains and lubrication.

Travelling stages are best described as flat conveyors,

consisting of a continuous endless chain of platforms running horizontally, or at a slight incline, on rollers and guide rails, and carried round sprocket wheels at each end of the journey at a slow speed—about 3 miles per hour. They are used to convey passengers along piers, across bridges, &c.; each person steps on and off when he wishes, and a handrail is provided to hold on by. One form of this traveller, employed at the Chicago World's Fair, had three platform bands side by side, running at increasing speeds of three, six and nine miles per hour, and by stepping from one to the other either speed of travel might be adopted.

Conveyors and chain elevators are simply, in most cases, endless drive chains with various forms of buckets or boards attached at intervals, and the sprocket wheels constructed to pass them round at each end. The buckets or boards slide loosely in a wooden trough on the lifting or working side, and generally hang loose on the other or empty side. Friction rollers are sometimes used on the buckets—running on guides—to relieve friction in travelling in the trough. There are other varieties of this type of conveyor: an endless band of leather, canvas or rubber insertion is used horizontally for loose material, as grain, flour, coal dust, &c., also an endless band of short flat platforms running horizontally (as described under travelling stages), with side strips to form a continuous trough, in which any kind of loose material may be carried moderate distances.

Worm conveyors or "creepers" are long, wide-threaded, long-pitched screws, revolving in a circular or semicircular trough, loosely; the material is fed in at one end and carried forward by the screw thread to the other end. An improved form of this conveyor is a spiral thick iron rod, without a centre spindle. As in continuous lifts, the principal wear and tear in conveyors is in the chains, chain centre pins and sprocket wheels; the troughs and boards or buckets wear a good deal also, unless friction rollers and guides are used. The power required to drive them is out of all proportion to the work done, but this is seldom a matter of any consequence. Worm conveyors are only used for short journeys of from

3 to 10 feet. Band and trough conveyors may run up to 200 feet or more in one band, and be continued if required by other bands or troughs, which may start away in any direction from the first band. Bands of course require provision for tightening up, and conveyor chains are tightened by moving the sprocket wheels or taking out a link or two.

Incline Lifts.—Besides the old form of mine incline tramways, there is a modern type used for passenger service. The rails are laid for a double track in most cases, but on long inclines a single track is sometimes used, with a passing place half way up, and switches opened and closed by the cars as they pass. The cars or trains of cars are connected by one or more steel wire ropes, which run over guide rollers and round a driving pulley at the top, fixed at the same angle as the incline, or in some cases, where a winding engine is used, there are separate ropes to each car or train, which run over vertical guide wheels to the double drum of the winding engine.

Where water is plentiful at the top of the incline, the lift is worked on the water balance system. In this method each car has a tank beneath it, and by a pipe and valve water can be run into the tank on the car at the top of the incline until it is heavy enough to draw up the loaded car at the bottom, the speed and stopping being regulated by a powerful brake on the rope pulley, which is either a V-grooved one, or one of the patent forms of clip pulleys fitted with V-clips round the rim. These clips grip the rope by its own tension and release it again as it leaves the pulley; this is a very economical plan of working. Ordinarily it is, of course, entirely dependent on the brakesman, but an automatic brake or speed governor may be used which regulates the maximum speed, and automatic stopping brakes are also applied to the cars to check them at the top and bottom of the incline in case the brakesman should fail to do so (see Safety Appliances, p. 320), the chief difficulty with these automatic brakes being the varying loads which occur in passenger traffic and make the stopping point uncertain. An engine is sometimes used to pump back the waste water to the top to be used

over again; in this way a small engine constantly running will work a heavy traffic. Many inclines, however, are used for lowering only; the weighted descending cars being used to bring up the empty ones. The working of these inclines is similar to the water balance inclines, but without the water, that is to say, they depend solely on the brakesman or upon automatic brakes.

Safety grips are attached for passenger service, which, on the breakage of the rope, instantly grip either the rails or a wooden mid-rail, and so prevent the cars running free to the bottom.

Hydraulic cylinders and rope gear (see next Chapter) are also used to work inclines of moderate length, and are the best plan possible, especially if water pressure can be obtained by gravitation from the top, in which case engine, pumps and accumulator can be dispensed with.

Where winding must be resorted to, it is always best to fix the engine and gear at the top, and for such heavy work as inclines worm gear is very unsatisfactory. A good modern direct driving or geared winding engine gives good results, greater speed and steadier motion; at the same time it is always easy to control, and can be stopped exactly at any given point by an automatic lever to the drum brake, so that it does not over-run its stops.

CHAPTER XXVIII.

HYDRAULIC LIFTING MACHINERY.

Hydraulic lifts and cranes have of late years reached a stage in which they have become absolutely essential to the existence of many buildings and businesses, and their safe and regular working is of the greatest possible importance, especially in the case of lifts for passenger traffic. In America very large numbers exist, and are constantly at work in the numerous high office buildings common in the States. Many of them have a travel of from 150 to 250 feet, with a speed of

X

300 feet per minute, and their safety, smooth working and general regularity are beyond praise. In this country they are also being rapidly introduced. The heights of our buildings being much less, the travel of these lifts seldom exceeds 100 feet, and up to this height the direct-acting ram lift is undoubtedly the best and safest, but will be impracticable for greater heights, because of the size and weight of ram required and depth of boring needed to sink the ram cylinder in the ground. In America ram lifts are almost unknown, all hydraulic lifts being varieties of the suspended or rope-geared short-stroke cylinder plan.

Hydraulic cranes preceded hydraulic lifts by many years. These are almost invariably of the short-stroke cylinder and chain-gear type, worked by accumulator pressure. The cylinder and gear are either fixed in a prepared pit or basement below the crane floor, or to an adjacent wall, or to the crane post itself. In the two former cases the chain is led under and up the centre of the crane post, and in the third case the water supply must be in the centre of the crane post, which revolves upon it, with a stuffing box to allow for the swivelling of the crane.

Travelling hydraulic cranes are also much used. To these the pressure water is led by a pipe laid alongside the track and fitted with branches at intervals, to which flexible or jointed pipes may be attached to connect with the crane, which can, of course, only have a limited travelling motion at each water connection. The pressures used vary from 100 to 1000 lbs., and the diameters and strengths of the cylinders vary accordingly. A separate short cylinder and chain gear are used to slew the crane a complete revolution. The starting levers are placed conveniently for handling, and connect as directly as possible with the valves. The steady smooth motion of these cranes, and their general handiness, power and speed have caused their general introduction wherever much crane work is done.

Deterioration in hydraulic cranes is generally the result of leakages and corrosion, bad water, defective lubrication and attention : chains wear badly under such conditions (see

Chain Gear, p. 267). Steel wire ropes are coming into service with larger sheaves, but the ropes must not be worked in wet situations. It is generally a mistake to fix the gear in a pit, because it is usually impossible to keep it dry, and it is also difficult to get at.

Hydraulic hoists are also constructed exactly as the cranes, but without the jib and slewing motion. The rope or chain is led over a cat-head or overhead pulley, and has a ball weight to the hook, as in a hydraulic crane, to return the empty hook.

A compact and useful variety of the short-stroke cylinder is made by using a bored cylinder and piston, fitted with a spur rack, which gears with a spur pinion keyed on the rope-drum shaft. Any multiplication of power or speed can be obtained in this way, the chief objection being the use of toothed gearing: but if cast-steel half-shrouded gear (both rack and pinion) is employed, and double helical teeth, a very fair approach to the smooth working direct or ram lift may be obtained in this way.

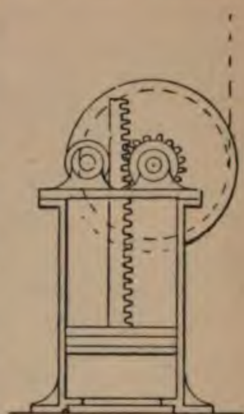


FIG. 306.

Fig. 306 shows the arrangement; the roller behind the rack is used to guide it and keep it in gear. For passenger lifts this plan is not much used, because in the cage the passage of the teeth in gear can be felt, and it is not so safe as rope gear.

Hydraulic winches are constructed also, having three motor cylinders and rams driving direct to a barrel shaft, or to a first-motion shaft, as in a steam winch. For details of this form of hydraulic motor see p. 233.

Hydraulic lifts are constructed on three general plans: (1) direct acting; (2) multiplying gear with short-stroke cylinder; (3) rack gear (as Fig. 306).

Direct-acting lifts are long hydraulic presses in which the cage is the follower, and raising its load is the work to be done by the ram. The cylinders are made of cast iron in lengths,

not bored, but with faced joints, the upper length having a deep stuffing box, neck and gland to guide the ram, and cast with large flanges to carry the entire weight on cross girders, or a stone foundation. The rams are usually of solid mild steel, but sometimes of steel tube, and in short, heavy lifts, of cast iron. They are turned accurately, and polished and jointed together by screwed unions (as Figs. 307 and 308). A stiff wide-flanged cast-iron head is fitted to the ram and bolted to the under side of the cage, which also is well guided, the object in view being to work the ram under conditions approximating as nearly as possible those of a column whose head and foot are firmly fixed and thus provided against flexure; and in proportioning the ram this is the basis of the calculation; that is to say, its stiffness as a column of a certain length is first provided for in its diameter, and if this is not enough to give sufficient lifting power the diameter is increased, but must not be decreased if too great for its load. In this case the pressure of the water may be reduced. The diameter of steel solid rams is usually from $\frac{1}{130}$ to $\frac{1}{180}$ the stroke. There is no overhead gear, and therefore nothing to break away and fall down the lift, unless a balance weight is used (see next page). The starting gear is an endless rope, as described (p. 298) for power lifts, but attached in this case to a starting valve, which controls all movements.

FIG. 307.

FIG. 308.

Multiplying gear short-stroke cylinder lifts, or hydraulic suspended rope-gear lifts are constructed on the same general plan as hydraulic cranes. The cage is suspended from the end of the rope, which, passing over the overhead sheave, is carried down direct to the cylinder sheaves. The cylinder is sometimes fixed vertically close to the lift, and sometimes horizontally on a basement floor, or in a pit prepared to receive it. The multiplication of speed is in the ratios of either 2–1, 4–1, 6–1, 8–1, &c. That is to say, the stroke

or travel of the cage is to that of the ram in the ratios named.

The American lifts are usually geared 2–1, and very long bored cylinders are used with pistons, two piston rods and two stuffing boxes in one cover. The cylinder is made in lengths, carefully jointed, so as not to cut the piston packing, and fixed vertically inside the lift well. Internal packings, however good, are always objectionable, and cause delays and stoppages to repair; there is no external means of tightening them up, and this system is gradually giving way to the ram and cylinder with external packing and gland. This plan, in fact, becomes absolutely necessary with the enormously high buildings now becoming common in America. There are lifts in use having a travel of 300 feet and over, for which, with the 2–1 ratio, the cylinder would require a length of over 150 feet; but a higher ratio than 10–1 is seldom adopted. With these higher multiplications the friction coefficient becomes high. It varies from about 15 per cent. with a 2–1 ratio, to about 40 per cent. at 10–1, and sufficient allowance must be made in the diameter of the ram to cover it fully.

Rack gear lifts are constructed with bored cylinders of short stroke, as described under Hydraulic Hoists, p. 307. These are geared down to any required ratio, fractional or multiple, and the proportionate diameters of rope drum and spur pinion arranged as may be required by circumstances of space, &c. The objection to internal or piston packing also applies in this plan, but with less force, because, the cylinder having an open top, the head can be designed to permit of tightening up the piston junk ring by a socket spanner, and any leakage is at once seen, but with the "Otis" and other American 2–1 internal piston types, leakage is only to be discovered at the end of the exhaust pipe, which is generally sunk in an underground tank away from observation.

Balancing gear.—The cages of hydraulic lifts may be, and, in fact, often are, balanced by a weight as in hand and power lifts, but there are many objections to this plan when passenger lifts are to be dealt with. Strong overhead sheaves and supports are necessary, which may break or work loose and

fall down the lift well. Extra ropes are needed, and a good deal of extra friction is caused by the extra dead weight. The weight itself sometimes breaks its rope and falls to the bottom. The cage would not fall in this case, but might run down very fast and cause some injury to itself and contents.

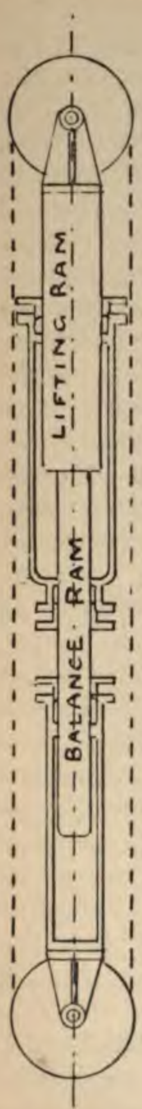


FIG. 309.

In some direct-acting ram lifts, heavy compensating chains are used for the balance weight; these introduce a great deal of friction. Should a cage break away from the ram of a direct-acting lift, the balance weight would descend rapidly and, propelling the cage up to the top with great force, probably smash it.

Overhead gear, from its position, is liable to be neglected, to run without oil, and cut deeply into its bearings—often on one side only—in consequence of the great weight suspended from it at all times. Cases are common where the spindles have worn completely through the pedestals and the wheel has canted over to one side so much that the chain or rope has run off it before any attention has been called to it.

To avoid these risks in passenger lifts, and improve their working also, balancing by hydraulic pressure is much used now. In a general way this may be described as dividing the lifting ram—either of the direct or multiplying form—into two parts or areas, one of which is permanently under pressure, and nearly sufficient to lift the cage, the other area of pressure is only in action when lifting, and suffices to raise the load; when descending, the water is exhausted from the lifting area, leaving only the permanent balancing area under pressure, but the cage, being a little heavier, in descending forces back the ram against this pressure, returning the water to the accumulator or pipes. There are

many methods—patent and otherwise—in use to effect this. The best of these plans are those in which external packings are used throughout. Many ingenious plans are objectionable because they involve internal pistons and bored cylinders. Different pressures of water are often used for this purpose, and the balancing cylinders are placed at any convenient position near the lift. For short-stroke cylinders the simplest balancing ram is that shown in Fig. 309. Direct-acting lifts require, in addition to a balance for the cage, a compensating arrangement to balance the ram itself as it emerges from the cylinder, to equalise, in fact, the difference between its weight in air and in water. If uncompensated, the speed of travel is not even but gets perceptibly slower towards the top. One method of effecting this has been described, p. 310. Other methods are by adding weight in sections to the balance ram as the cage descends, taking them off one by one as it ascends, by an automatic arrangement ; variable leverage is also employed and a heavy chain of weights (running over a sheave), which add their weight gradually to either side as the rams travel in and out.

Complicated devices are, however, to be deprecated as tending to accidents and breakdowns.

CHAPTER XXIX.

HYDRAULIC LIFTS. ACCESSORIES.

General Details.

Hydraulic Cylinders, Rams and Pistons.—(See also Pumps, Chapter VI.) The cylinders are almost invariably of cast iron. The mixture should be a tough one and tolerably close grained, as with high pressures the water oozes through coarse-grained metal. The coarseness of grain depends largely upon the thickness of the casting, being coarser in a thick casting than a thin one. The castings should always be run on end

with a good head; castings run horizontally or even on a slope are almost invariably spongy on the upper inner side, and if they are afterwards bored, turn out expensive wasters. Attempts are made sometimes to fill the spongy place with sulphur composition, and if set to work the result is frequent and vexatious renewals of the piston packing. With the higher pressures now in use (700 lbs. is common) this is a serious matter. Ram cylinders which are not bored are not quite so important as to clearness of casting, but ought to be tested before boring the neck. All cylinders should be tested by water pressure to one-and-a-half times the working pressure, and any leaks effectually stopped. Pin holes can be drilled out and plugs screwed in. Small spongy places can be treated in the same way. Rams, if of cast-iron, must always be cast on end, turned true and polished and be of exactly the same diameter throughout. If jointed, the joint should be a screwed one, unless of sufficiently large diameter to have inside flanges and room for a boy to get inside to insert the bolts. Joints must also have a watertight packing between them, as Fig. 310, to prevent water leaking into the inside. Steel rams are made of mild Siemens-Martin or Bessemer steel, which turns up clean and bright as silver, and can be depended on for even quality and toughness. A muff gauge should be used to ensure accuracy throughout. Lumps in a ram cause tight places and slowness in the motion of the cage, and loose places cause leakage which rapidly corrodes the ram. Stuffing boxes should be deep, especially with high pressures. Necks and glands also should be of good depth to guide the ram. Packing should be used whenever possible, for though leathers work with less friction, they are very difficult to get on and off. It is often a dangerous and troublesome job to disconnect a ram for the purpose of slipping a new leather collar on it. Their life also is very uncertain. Lift rams require frequent cleaning and must be regularly greased. The glands also need attention and tightening, to prevent leakage and consequent corrosion. The packing must for the same

FIG. 310.

reason be often renewed. It must be remembered that glands can easily be tightened up so much in excess by an unskilful hand as to entirely stop the ram. Excessive pressure on the packing soon cuts and grooves the ram, and should be avoided by more frequent renewal. In the "Otis" and other piston lifts a combination of leather and packing is used, as Fig. 311, which lasts well and is probably the best piston packing that can be devised. Rings as piston packing are used to a limited extent, usually of phosphor bronze. Steel or cast-iron rings are of no use, but the cylinder boring must be very true and smooth if rings are used. Grease is the best lubricant, but should be free from free acids. Where the water is used over again it is usual to dissolve soap in it as a lubricant, and this answers satisfactorily with soft waters, but hard waters become flaky and harsh, and the soap does no good, but, in fact, harm, by choking the pipes, &c.

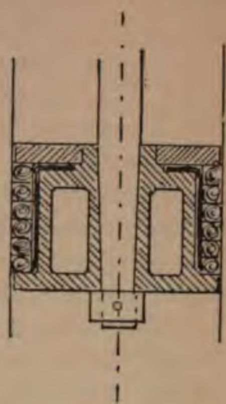


FIG. 311.

FRICTION OF CUP LEATHERS IN HYDRAULIC CYLINDERS.

Diam. in inches.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Friction per cent.	2·0	1·33	1·00	·80	·66	57	·5	·44	·40	·38	·33	·30	·28	·26	·25	·43	·22	·21	·20

Rule: friction = diam. × press × C.
C = ·0471 (badly lubricated) or ·0314 (well lubricated).

Multiplying Gear.—The essential points that claim attention in this part of the machinery are the following:—Sheaves should be of large diameter, and grooved to take the rope or ropes, as Fig. 312. Three, four, or five ropes are now common for passenger lifts. The sheave centres should be of steel, and steel bushes be driven into the sheaves, the centres to be of as

small diameter as will allow ample shearing strength. They must be spaced to line, so as to divide the strains equally, and so that the sum of the pull of the ropes is in the centre line of the ram. If the cylinder is fixed horizontally, guides are required for the ram head to prevent cross strain or jamming in the cylinder neck. Rollers are generally used for this and planed guide bars. Efficient guards are required to all sheaves to prevent the ropes running off.

FIG. 312.

Pipe work and Valves.—All pipe connections to cylinders and valves should be flanged; it is best, in fact, to use flanges all through, especially for high pressure, as screwed unions sometimes develop leaks which are difficult to stop. Such flanges are made strong and heavy, as Figs. 136 and 137, p. 107. Standard sizes of flanges are usually adopted by makers to suit all valves, &c.; this saves a lot of trouble with special flanges. The valves required are plain screw-down stop valves or sluice valves, check valves, non-return stop valves, and starting valves, and they vary in strength and in construction according to the pressure used. The ordinary commercial sluice valves and check valves, with gun-metal seatings, &c., are used for pressures up to 100 lbs. per square inch. For higher pressures specially heavy screw-down and other valves are made. Each maker has his own pattern. They often leak, by the high-pressure water and grit cutting the seating and valve.

Starting valves are of numerous forms: the object aimed at is chiefly to be absolutely watertight, and at the same time as near frictionless as may be. With high pressures a very small valve may be so hard to move as to require too much strain exerted at the starting rope. The plain slide valve is best for all hydraulic purposes to the extent of its frictional resistance. For higher pressures or larger valves than can be easily operated by hand, various patent and other types of cylindrical valves are used (see 'Engineers' Sketch Book,' p. 184); some of these are moved by the water pressure, an auxiliary valve being first opened by the starting rope, this

llows the pressure water to act on the large valve to open t. All these starting valves require lubrication ; methods of pplying oil are described at p. 106.

It is hardly necessary to say that all the internal parts of ll valves for hydraulic use must be of brass, gun-metal or hosphor bronze, the latter metal being used for the higher ressures, for valves, faces, seatings and spindles.

Pipes are of wrought and cast iron. The latter are used or low-pressure services up to, say, 100 lbs. per square inch. Wrought-iron pipes can be obtained from the makers—also teel pipes—to withstand any required pressure. A stock is usually kept of hydraulic pipes and fittings of various strengths, by tube makers. Elbows and tees should be avoided and, generally, the pipes laid as direct as possible. Screwed joints are made with red-lead paint. Flanged joints with rubber nsertion for low pressures, and gutta-percha cord, leather washers or lead cord for high pressures. Flanges should be grooved on the joint faces to prevent the insertion from blowing out. All pipes and valves require testing before use. Pinholes and flaws frequently show when tested, and can be made good without difficulty before leaving the works. The sizes of pipes and valves are determined by the *quantity* of water passing through them, and are not affected by the pressure. A speed of 250 to 300 feet per minute may be taken as a basis for calculation. The pipes must be laid so as not to trap any air. Accumulation of air can be let off by an air cock at the highest point in the system.

Air vessels are used on the pipe from the accumulator in some instances to prevent shock from sudden starting and stopping.

Tanks and Accumulators.—There are several methods in use for supplying pressure water for hydraulic work.

(1) The water may be taken direct from the water company's main ; (2) it may be taken from an overhead tank, fixed as high as the building will allow ; (3) an accumulator may be used ; (4) it may be pumped direct to the lift cylinder. Each method has its pros and cons.

1. To take it direct from a main is decidedly the simplest

and cheapest, but it must first be ascertained whether the pressure available is sufficient, then if the main is large enough to supply the intermittent service required without great loss of pressure. This can only be determined by testing it. A valve as large as the service pipe wanted can be attached to a convenient hydrant, and a pressure gauge applied to see what pressure is indicated when the valve is fully opened. We have known a pressure of 48 lbs. to entirely disappear when a 1-inch tap was opened in this way. Supposing these points to be satisfactory, there remains the possibility of the water being turned off just when wanted for the lift. The Water Company can satisfy enquiries on these points.

2. *An overhead tank* is a very common arrangement. It should be large enough to hold enough water for, say, 10 journeys of the lift. A small continuous service with ball tap will keep it supplied. The water may either be exhausted from the lift to a drain or delivered into a tank and pumped up again. The latter plan is very commonly adopted, and a small gas engine and pump used to run almost continuously for this purpose. This plan has the advantage of steady and even pressure, with the certainty that the lift will not be stopped from the water supply being cut off for short intervals, as often happens when connecting new service pipes, repairing bursts, &c.

3. *An accumulator* is always used for high pressures, except where—as in London—there is a public high-pressure service. There are two kinds of accumulators; the air vessel and the loaded ram. The air accumulator is much in use in America; it is simply a cylindrical reservoir of wrought iron or steel, large enough to contain three or four times the contents of the lift cylinder. The water is pumped into it by a steam pump having an automatic stopping and starting gear, regulated by the pressure in the accumulator. Such a vessel must be very strongly made to stand pressures of from 300 to 700 lbs. per square inch, and is, in fact, rarely used for such pressures, but rather for pressures up to 300 or 350 lbs. In this country, however, 700 lbs. is a common pressure, and for this the loaded ram is preferable. This is simply a

ylinder and ram fixed vertically, to the latter of which veights are attached, so that the pressure on the water in the ylinder rises to the figure required. Cast-iron weights are nost generally used, either resting on a heavy cross-head or uspended from one by bolts; but in some cases a large vrought-iron box or receptacle is fixed on the ram-head and illed with any cheap heavy material, such as shingle or ravel. The pumps deliver the water into the accumulator vhich, when full, stops the pumping by an automatic lever ear and starts it again when it falls. Pumps for this purpose re described on p. 105.

4. Pumping direct into the lift cylinder is rarely employed except on short-stroke goods lifts, and for hydraulic presses (see p. 105). It is too slow and too jerky for passenger service, requiring also a powerful set of pumps and engine which are, as a rule, only required for a short time at intervals and therefore not an economical arrangement.

Accumulator cylinders should either have deep necks to guide the ram and its load, or external guides fixed to rigid supports for this purpose. Accumulators rarely give any trouble beyond occasional repacking of glands.

Air cocks are necessary at the upper parts of all cylinders and pipes, to discharge accumulations of air which cause unsteady motion in the lift (see p. 108).

Starting Gear.—This is constructed the same as for power lifts (see p. 298), but the rope is connected in this case to the wheel or lever, which operates the starting valve. A long balanced lever is better than a wheel, works more freely in practice, and can generally be easily applied. The rope is kept tight by a lanyard or screw coupling. Some makers, however, use a single rope passed over a pulley at the top of the lift, and attached to a weight at each end, sufficient, either of them, to move the valve. This rope is always tight by the tension of the weights. Smooth soft rope is used for hand ropes, and about $\frac{3}{4}$ inch diameter.

Cages and Guides.—Passenger lift cages are very elaborately finished as a rule. The wood work is framed and panelled with carved ceiling, cornices, mouldings and en-

PRESSURES OF COLUMNS OF WATER.

Diam. Ram in inches.	Pressure in lbs. per square inch.													
	25	30	35	40	45	50	100	200	300	400	500	600	700	1000
	Total Pressure on Ram in lbs.													
½	4·90	5·88	6·87	7·85	8·83	9·81	19·63	39·26	58·89	78·52	98·15	117·78	137·41	196·30
⅝	7·67	9·20	10·73	12·27	13·80	15·34	30·68	61·36	92·04	122·72	153·40	184·08	214·76	306·80
¾	11·04	13·25	15·45	17·66	19·87	22·08	44·17	88·34	132·51	176·68	220·90	265·02	309·19	441·80
⅞	15·03	18·03	21·04	24·05	27·05	30·06	60·13	120·26	180·39	240·52	300·65	360·78	420·91	601·30
1	19·63	23·56	27·48	31·41	35·34	39·27	78·54	157·08	235·62	314·16	392·70	471·24	549·78	785·40
1½	44·17	53·01	61·84	70·68	79·51	88·35	176·71	353·42	530·13	706·84	883·55	1060·26	1236·97	1767·10
2	78·50	94·20	109·9	125·6	141·3	157·0	314·10	628·20	942·30	1256·40	1570·50	1884·60	2198·70	3141·60
	Total Pressure on Ram in tons.													
3	·078	·094	·110	·125	·141	·158	·315	·930	·945	1·260	1·575	1·891	2·206	3·151
4	·140	·167	·195	·223	·250	·279	·560	1·121	1·682	2·242	2·803	3·364	3·925	5·609
5	·218	·262	·306	·350	·393	·437	·876	1·752	2·629	3·505	4·381	5·258	6·134	8·765
6	·315	·378	·441	·504	·567	·630	1·262	2·524	3·708	5·048	6·310	7·572	8·834	12·622
7	·429	·515	·600	·711	·773	·858	1·717	3·435	5·153	6·871	8·589	10·307	12·025	17·180
8	·560	·762	·785	·897	1·009	1·123	2·243	4·487	6·731	8·975	11·218	13·462	15·706	22·439
9	·709	·851	·993	1·135	1·277	1·419	2·839	5·679	8·519	11·358	14·198	17·038	19·878	28·400
10	·876	1·051	1·226	1·402	1·578	1·753	3·506	7·012	10·514	14·022	17·531	21·037	24·543	35·062
11	1·060	1·272	1·484	1·696	1·908	2·120	4·242	8·484	12·727	16·968	21·212	25·450	29·696	42·425
12	1·261	1·513	1·765	2·017	2·270	2·522	5·048	10·097	15·145	20·194	25·243	30·291	35·340	50·489
13	1·480	1·777	2·073	2·369	2·666	2·962	5·925	11·850	17·776	23·701	29·627	35·552	41·478	59·255
14	1·717	2·061	2·404	2·748	3·091	3·435	6·871	13·743	20·615	27·487	34·359	41·231	48·103	68·722
15	1·971	2·366	2·760	3·155	3·550	3·944	7·888	15·777	23·665	31·555	39·441	47·333	55·221	78·890
16	2·243	2·691	3·140	3·589	4·037	4·486	8·975	17·951	26·927	35·903	44·879	53·855	62·741	89·759
17	2·532	3·038	3·545	4·051	4·558	5·064	10·133	20·266	30·399	40·532	50·665	60·798	70·931	101·330
18	2·839	3·407	3·975	4·542	5·110	5·678	11·359	22·719	34·079	45·439	56·799	68·158	79·518	113·598
19	3·163	3·796	4·429	5·062	5·695	6·323	12·675	25·314	37·971	50·628	63·285	75·942	88·600	126·575
20	3·505	4·206	4·907	5·608	6·328	7·011	14·025	28·050	42·075	56·100	70·125	84·150	98·175	140·249

Diam. Ram in inches.	Pressure per square inch in cwts.										
	10	15	20	25	30	35	40	45	50	55	60
	Total Pressure on Ram in tons.										
½	·098	·147	·195	·245	·29	·34	·39	·44	·49	·535	·585
⅝	·153	·23	·305	·383	·455	·535	·61	·69	·765	·84	·92
¾	·22	·331	·44	·552	·66	·77	·88	·99	1·1	1·21	1·32
⅞	·30	·45	·60	·75	·90	1·05	1·2	1·35	1·5	1·65	1·8
1	·392	·589	·785	·98	1·175	1·37	1·57	1·765	1·96	2·155	2·355
1½	·883	1·325	1·765	2·205	2·65	3·09	3·53	3·975	4·415	4·855	5·3
2	1·57	2·355	3·14	3·925	4·71	5·495	6·28	7·065	7·85	8·635	9·42
3	3·84	5·3	7·06	8·83	10·6	12·36	14·13	15·9	17·67	19·43	21·2
4	6·28	9·4	12·56	15·7	18·84	21·98	25·13	28·27	31·41	34·55	37·69
5	9·81	14·7	19·63	24·53	29·45	34·35	39·27	44·17	49·08	53·99	58·90
6	14·13	21·2	28·27	35·33	42·41	49·47	56·54	63·61	70·68	77·75	84·82
7	19·24	28·85	38·48	48·1	57·72	67·34	76·96	86·58	96·21	105·83	115·45
8	25·13	37·67	50·26	62·82	75·39	87·96	100·53	113·09	125·66	138·22	150·79
9	31·80	47·7	63·61	79·51	95·42	111·32	127·23	143·13	159·04	174·94	190·85
10	39·26	58·9	78·53	98·67	117·80	137·43	157·07	176·71	196·34	215·97	235·61
11	47·51	71·25	95·03	118·78	142·54	166·3	190·06	213·87	237·58	261·33	285·09
12	56·54	84·7	113·09	141·36	169·64	197·91	226·69	254·46	282·74	311·01	339·29
13	66·36	99·52	132·73	165·91	199·09	232·27	265·46	298·64	331·83	365·01	398·19
14	76·96	115·42	153·98	192 41	230·90	269·38	307·87	346·35	384·84	423·32	461·81
15	88·35	132·52	176·71	220·88	265·07	309·24	353·42	397·6	441·78	485·96	530·14
16	100·53	150·75	201·06	251·32	301·59	351·85	402·12	452·38	502·65	552·96	603·68
17	113·49	170·17	226·98	288·72	340·47	397·21	453·96	510·70	567·45	624·19	680·92
18	127·23	190·8	254·46	318·07	381·7	445·31	508·92	572·53	636·17	699·78	763·40
19	141·76	212·62	283·52	354·4	425·29	496·17	567·05	637·93	708·82	779·7	850·58
20	157·07	235·57	314·15	392·68	471·23	549·77	628·31	706·85	785·39	863·93	942·47
21	173·18	259·72	346·36	432·95	519·54	606·13	692·72	779·31	865·9	952·49	1039·08
22	190·06	285·07	380·13	475·16	570·19	665·22	760·26	855·29	950·33	1045·36	1140·39
23	207·73	311·55	415·47	519·33	623·21	727·07	830·94	934·8	1038·68	1142·55	1246·42
24	226·19	339·22	452·38	565·47	678·58	791·67	904·77	1017·87	1130·97	1244·06	1357·16

richments, bevelled mirrors and decorations. Another favourite type of cage has all the upper part above the seats constructed of light ornamental open ironwork in scroll foliage, &c. Goods lifts have plain strong framed cages of deal, and are painted.

The guides and their parallelism are important in allowing smooth motion to the cage. Wood scantlings are used (Fig. 313), and for the better class of lifts these are faced with planed guide bars (Fig. 314), or planished round shafting bars are used, as Fig. 315. These are fixed perfectly upright, straight and parallel by gauge. The cage has gun-metal runners planed to fit the guides, and for the best work, fitted with springs to keep them close in gear at all times, and prevent side play of the cage.

FIG. 313.

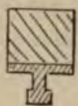


FIG. 314.

FIG. 315.

For facilitating calculations relating to hydraulic lifts the tables on pp. 318 and 319 will be found useful.

CHAPTER XXX.

SAFETY ATTACHMENTS.

Safety Appliances.—Lift installations are prolific in accidents, and perhaps no general class of apparatus has been more industriously improved and schemed at than safety apparatus. Out of the general host there are some types that stand out as more practicable and likely than others, and they may be classed as follows:—(1) cam grips which grip the guides when the rope breaks; (2) pawls which either dig into the *wood* guides or engage with iron ratchet teeth on the guides; (3) wedges which jam the cage tightly between the guides; (4) extra ropes left slack so as to come into use only when the working rope fails; (5) governor gear which prevents the cage travelling at excessive speed (illustrations of these

appear in the 'Engineer's Sketch Book,' p. 182); (6) special valves, set in action by sudden fall of pressure, to prevent the cage falling rapidly should the cylinder or supply pipe burst; (7) for mines there are also apparatus to prevent overwinding; automatic brakes and throttling gear attached to the winding engines for the same purpose; cage safety catches, grips, &c., to come into use automatically should the lifting rope or attachment break; and various forms of pit guards to prevent accidents from persons or materials falling down the shaft. In lifts where the cage is suspended by more than one rope, mechanism is employed to lock the cage in its guides should any one rope break, the tension of the others being utilised for this purpose.

The essentials of an efficient safety apparatus are these: (1) it must act instantly, before the cage has commenced its descent: a heavy cage, once in full motion down, will tear or break almost any check applied to it, especially if it is applied suddenly, as a pawl engaging with ratchet teeth; (2) for this reason the apparatus will be safer if fixed under the cage than on its top; (3) it should act whenever the speed becomes excessive, but as a brake in this case, so as not to arrest the cage too suddenly; (4) it should act when any one of the cage ropes becomes broken or slack from any cause.

It would appear from these conditions that rack and pawl gear is the least satisfactory of all, as, though it fulfils the first condition, it is opposed to both 3 and 4. Cam gear which grips the guides, or wedge gear which jams the cage by excess of friction, would appear to be better adapted to meet all the circumstances, as they will instantly arrest a cage suddenly freed from suspension, and in case of a cage travelling too fast they would slip sufficiently to obviate a too sudden grip. For the governing device, however, it is generally advisable to use an independent gear which acts upon one or more of the ropes not employed in lifting; thus one of the balance weight ropes is suitable; or it is sometimes applied to the overhead sheave, over which all the ropes travel, with the effect of checking its speed of revolution. It is evident, however, that to effect this the ropes must run in

V-grooves, or that the brake strap or block must act on the ropes themselves, as they go round the sheave. This kind of check must not be depended on to stop the cage however, because it acts only by the motion of the cage itself, and therefore will only retard and not stop it. There are other devices, however, set in motion by the governor, which, by throwing out a catch, absolutely stop the cage by locking the overhead sheave; others effect the same purpose by gripping one of the ropes, which, being strained, throws into action the safety grips on the cage and thus stops its descent entirely.

Guides upon which safety apparatus may act require to be very strong and well supported. For struts, pawls or wedge-gears the guides must be backed by a wall, or they will spread and allow the cage to fall.

Accidents from the actual breakage of ropes and attachments are, however, comparatively rare; most lift accidents are caused by persons falling down the lift, or getting jammed by the cage through getting in or out while it is in motion, inability to stop it, &c.

To meet these classes of accidents a great number of inventions involving automatic doors and similar safeguards, have been proposed from time to time, but few of them have come into use. Most of them fail in practice because they introduce new dangers in avoiding others. Automatic movements are dangerous in nearly every case, they start unexpectedly and catch the unwary.

The device that has become general is simply to provide lift doors that can only be opened from the inside, that is, from the cage, reserving, however, a master key, by which the doors can be opened from the outside, which is kept in a known place and only used in case the cage becomes fixed. This plan affords absolute security from accidents from falling down the lift and also from getting in and out before the cage is at rest, assuming that the cage is in the charge of a qualified attendant. The doors and enclosures of the lift must not allow a person from any point to put his head into hte lift well to look up or down; many persons have had their heads crushed in this way. After all, it is probable that

the best safety device is a thoroughly well constructed lift with ample margin of strength in every part, and—what is of great importance—periodically examined by an expert. This is now becoming the practice of the best makers, and is a better guarantee of safety than any mechanical device whatever. A further safeguard is to always employ a reliable and steady man, who understands his work, to operate the lift, and not to allow every one who likes to use it. This, in fact, may be said of all hoisting apparatus except that worked by hand power. Mines, pits or wells having landing places only at top and bottom, are provided with an enclosure or railing which is lifted by the top of the cage when it reaches the top level, and is deposited again when it descends.

All safety apparatus, however, suffers from want of use, that is to say, becomes unreliable from neglect, accumulation of dirt or grease, and often gets rusted up, so that at the critical moment it generally fails to act, and this applies to all sorts of gear as described above, unless they are so arranged that the daily and ordinary running or stopping of the lift in some way keeps the parts in motion. Those gears which are fixed beneath the cage do not so readily get clogged with dirt, but may rust up as easily as others, perhaps more so, from the fact that many cages when standing overnight rest in a pit in the basement, which is often damp or wet. Overhead devices, again, are rarely looked at because they are not easy of access. There are other objections to safety gears: some of them are too sensitive and go on when least expected, giving the passengers a fright and a long wait until released; sometimes they partially grip through stretching of ropes, wear, &c., and then, by rubbing hard on the guides, act as a brake or skid, causing slow speed with grinding, uneasy motion.

The existence of a safety gear, however, serves to give some confidence, and if it is frequently examined and occasionally tested may still be of value. It is now becoming the practice in public lift installations to exhibit a notice or certificate of the testing in a prominent place, as an evidence that the lift is well cared for.

SECTION VII.—*TRANSPORT.*

CHAPTER XXXI.

ROAD VEHICLES AND TRAMWAYS.

UNDER the heading of transport we include vehicles of all kinds employed for carriage or locomotion either on railroads, tramways or ordinary metalled roads, as also the rails, tram-plates and gear connected with them, signals, &c. The classification will therefore include road vehicles, traction engines and steam rollers, tramways, engines and cars, railways, locomotives, wagons, carriages and signals. The power and motors employed in aiding locomotion or traction by these means are steam engines, electric motors, compressed air reservoir engines and endless wire ropes driven by steam engines, also horse traction.

Vehicles on Common Roads.—These scarcely come within the province of the engineer, though perhaps if they did we should have some notable improvements in them to speak of. There are certainly some points that want improving, especially in the braking, stopping and starting of the larger or public conveyances, as omnibuses and tramcars. With the form, capacity, seating arrangements, &c., we have nothing to do. One or two general features of importance may be pointed out to which more attention ought to be paid than is now the case. Firstly, in the greater number of vehicles the centre of gravity is too high, causing oscillation—dangerous in the case of tall omnibuses, &c.—and excessive wear, besides adding something to the tractive effort necessary. Secondly, the old-fashioned overhung axles and wheels are very unscientific, and cause a large percentage of breakages besides

excessive wear and tear; outside bearings ought to be general, instead of exceptional.* The axles might then be similar to railway vehicles, which have been brought to considerable perfection, or in the case of low bodied cars, outside and inside bearings and centre pins with coned bushes will give infinitely better results than the present overhung bearings. As it is, most vehicles are built to their present height merely because the car must be above the axles and springs; thus the centre of gravity is high, and with high floors there is a great deal more lifting and hard work in loading and unloading than there need be. The general introduction of roller or ball bearings also would be an immense advance on all the present axle boxes.

Brakes and Skids.—The relative value of these has seldom been considered. A skid saves wear of the tyre, but it has been proved by Captain Galton's experiments that a wheel should never be skidded by the brake, because the frictional bite between the wheel and rail is there less than that of the wheel and brake block; it follows, therefore, that the greatest available braking is obtained when the pressure on the wheel is approaching the skidding point, but does not actually prevent its revolution. Skids are troublesome to put on and take off, but effective. The breakage of the skid chain is the greatest risk, as then there is no check to the vehicle. Brakes would be more effective if they gripped the wheel on both sides, so as not to put cross strain on the axle. The best lining for them is leather, but both wood and cast iron are used, and there are two ways of applying the pressure, by leverage, from the foot or hand, and by screw. The latter is the best for heavy vehicles. For omnibuses, breaks, &c., an effective starting gear, using the brake power—stored up—would be an acquisition, and many schemes have been tried, but with only partial success as yet.

Axles and Axle-boxes.—Axles are invariably coned, but nearly always of wrought iron, and soon become crystalline and break from the continual jar and vibration they suffer.

* We observe that some omnibuses are now being fitted with outside bearings and springs in London, and are certainly steadier in running than the old type.

Axle boxes are usually of chilled cast-iron, and of course not bored, but ground out to fit the axle. The first box is generally a good fit, but new axle-boxes are seldom fitted properly to the axle, for the axle always wears oval and should be turned and the box bored or ground to a good fit to wear well; but carriage builders have no machine tools for this purpose.

Traction Engines and Steam Road-rollers. Steam Carriages.—Steam on common roads has been promised for many years past, but the existing laws restrict its use in so many ways that, except in very slow and heavy vehicles, it is practically prohibited, and there is no immediate prospect of any alteration of existing legislation. But it has been shown by Serpollet, of Paris, and others that the problem of steam vehicles for general traffic is easily solved, and in fact, such vehicles are now in use in France with much success. Certainly a steam engine will not be more erratic or intractable than a quadruped, which often exhibits a will of its own. It is certain also that gas and oil power are readily applicable with safety to these purposes, to which may be added electric accumulator motors and compressed air storage motors.

We are, however, for the present, confined to slow running traction engines, which, constructed as they are, with heavy running gear, high pressure, open exhausting chimney blast and ungainly appearance, are certainly not calculated to further the agitation for the removal of the present restrictions. But the law has produced this type of engine and now quotes its ugliness and faults as reasons for refusing better terms to engineers. Hence the field of usefulness is restricted to the drawing of heavy machinery, girders, and such work on common roads as is too heavy for horse traction, and this is effected at two or three times the cost that would be incurred with engines designed for greater speeds and working under more favourable conditions.

Traction engines and road-rollers are essentially portable engines which drive by a chain only, gearing direct to their own travelling wheels. The front pair has a swivelling gear for steering, and a compensating or "equational box" gear on

the driving axle for driving the wheels proportionately at variable speeds in turning corners and curves, and they are usually provided with a small driving cab, coal bunker and water tank. In this class of engines the chief source of failure and injury is the straining and jolting arising from irregularities of roadway and insufficient elasticity in the framing; in fact, in this latter respect they will admit of great improvements.

Elastic wheels, so called, are commonly used, but effect little in reducing the jar in running. American makers also provide elastic driving connection between the driving wheels and the spur gear, ingenious in conception but troublesome in practice, involving a good many joints and springs. Improvement must be looked for in providing springs to the driving wheel axle boxes, as is done in the locomotive, and of course adding a method of driving which allows of considerable rise and fall in these axles. Their tractive power can also be increased by either coupling the four wheels or bringing the driving axles further under the engine, which is done by some American makers. Common roads are not calculated to run such heavy machinery as a rule, so that sinking of the wheels into ruts and holes, crushing in small bridges and sewers are by no means uncommon accidents, and necessarily result in injuries to the engines as well.

Country, agricultural and general engineers find the repair of these engines and of portable engines generally an important line in their books. Such repairs as apply to the engine and boiler have been referred to (Chapters I. to V.). Those specially relating to the travelling gear comprise new bolts and rivets to replace those shaken loose or broken, new wheel arms of wrought-iron bars or rods; new rim fillets, usually riveted on; new bearings, which wear rapidly from the dust and vibration which are inevitable in a road engine, and sometimes new gearing, steering gear, worm and wheel, and occasionally the steering chains require renewal; the former should be of cast-steel and the latter of hard iron, short link pattern. The leading axle sometimes breaks, being of the ordinary cart pattern, with overhung wheels, and the

bushes of these require renewing and new brass cap nuts occasionally.

Steam road-rollers give less trouble with the road wheels, and are very heavy and very strongly built. The distribution of weight is better also than in the traction engine, being proportioned as nearly as may be to the width of the tyres, to give an equal crushing pressure over the whole width traversed; and the weight of the wheels to a great extent minimises or takes up shocks and vibration from the irregularities of the road; there is therefore less need of springs to absorb the jar, and the total of repairs needed is much smaller than with traction engines.

Tramways. Engines and Cars. The introduction of the tramway into public streets, in competition with the ordinary road conveyances, is not quite an unqualified success here or in America, where they are the recognised form of public passenger conveyances; but, as the Americans run their trains through the streets, and employ an enormous number of level crossings, the incongruity of rails in the streets, amongst the common horse traffic, does not strike them in any way. Tramways are certainly convenient to the passenger, afford smoother travelling than omnibuses, but are a nuisance to the general carriage and van traffic of the streets by monopolising the roadway, and by the obstruction to ordinary cart wheels caused by their rails and crossings, though in England these are vastly better laid than in America. In fact the whole question turns practically on the effectiveness of the rails and the excellence of their laying. If they can be so smoothly set with the road metalling or cubing as to present no obstacle to cart traffic, there is not much left to complain of.

The various methods of traction comprise (1) horse traction; (2) wire rope; (3) electric motor; (4) compressed air reservoir and motor; and (5) steam engine, all of which have been tried, and have met with some measure of success; the first seems to still maintain its ground most tenaciously, and perhaps has the fewest objections that can be urged against it. Drivers understand horses, they are easy to

manage, easily changed, do not involve any special appliances, nor occupy any valuable space in the car, and are cheaper to maintain on the whole.

The wire rope plan is in use chiefly in America. It involves a large central buried tube, with a slit in its upper side for the car grip to travel in. The wear and tear of the rope is heavy, and the power lost in friction enormous. A broken rope entirely stops the traffic for a time, and serious accidents often result from the grips fouling or getting jammed on the rope, when the car goes careering round the town, free from all control, until it is smashed, or the engine stopped. The central tube also makes an expensive plant, and cuts up the roadway badly, so that in America, where they are in use, the roads are the worst in any civilised country. The advantages claimed are speed, centralisation of driving power in a large economical modern steam engine, and easy handling of the cars.

Electric motor gear has also the advantage of centralisation of power, though the loss by leakage is great. There are two methods of fixing conductors, either a central or side rail is employed or else an overhead naked wire. The former is defective from leakage, and causes sparking and accidents; the latter is certainly not taking to the eye, and gives a deal of trouble to fix and maintain, with the "fishing rod" sort of car connections running on them. It does not strike one as being a sound mechanical job, but make-shifty; some better method will need to be devised before this plan will obtain much favour. Electric motors also run at such high speeds that they cannot possibly be long lived, and the speed has to be reduced by gearing, which complicates matters.

The compressed air reservoir scheme, with simple motor of same form as a steam engine, ought to have been successful, but failed in practice, chiefly because too high an initial pressure was employed in order to reduce the size of air reservoir, and the gradual reduction of pressure, as the reservoir emptied, was difficult to deal with. High pressure air is costly (see Chapter XIV.), but there need be no trouble or complication in employing it in a car motor,

and as this plan also possesses the merit of centralisation of power, it ought to be successful, especially as nothing is required in addition to the ordinary rails and a brake on the car, the motor and reservoir being fixed beneath it; there is also no smoke or steam, heat or noise to frighten horses.

Steam engines, in fact tramway locomotives, are used in some towns, with good results generally; they are not economical, but can be handled like a locomotive, and possess power and speed; they have, however, the faults of lack of centralisation. The engine must be separate from the car, it is an expensive machine, inclined to be noisy, too bulky, the exhaust steam cannot be properly condensed, and there is some smoke and heat from it that are much objected to. The steam is condensed as far as can be by an air condenser—a series of tubes arranged on top of the engine, exposed to the air—but this is clearly more effective in winter than in summer, and adds nothing to economical working, as no vacuum is obtained by it. Like the compressed air method, however, it involves no additional rails or underground tubes, and has on this account been accepted as a fair solution of the problem.

The different motors described have been treated of generally under their particular headings, and we can here only allude to any special features of application to road traction.

In the wire rope system, the ropes run, of course, over grooved pulleys, and are sometimes three or four miles long; the friction is enormous, necessarily so, increased by the great speed adopted, from fifteen to twenty miles an hour. The ropes run until they break, and the continual hitching on and off of cars, and in many cases, as in Chicago, trains of two or three cars, must cause great strain at such a speed. The wear and tear, therefore, fall heavily on the ropes, guide sheaves and bearings, car grips and brakes; these latter are worked by one man, with two levers; the grips are out of sight in the rope tube, and hence cannot readily be inspected.

In the electric method, the wear comes on the conductors, switches, motors and commutators and the gearing, all of them expensive to renew. Compressed air motors and

reservoirs are not costly to repair; the reservoirs will last as long as the cars, and the motors, from the absence of heat, run well for a long period with ordinary care.

The steam method suffers chiefly from the unevenness of the road, and the weight of the engines tells upon the permanent way much more than any other system of driving, especially on the short curves and switches, which are necessary in tram roads, and which necessitate very short wheel bases. The air condensers complicate and add to the weight and cumbersomeness of the engine, and the first cost of the running plant is certainly heavy. In the engines themselves, the wear falls chiefly on the tyres and axle boxes. The short wheel base, quick curves and gradients, bring a great deal of wear on these.

The engine running gear, being hard at work perhaps fourteen hours a day, of course needs a good deal of attention and frequent setting up. The brake blocks also wear rapidly, being in constant use. Cast iron is generally employed, and in some cases, shoes or faces only are renewed; these being separate from the brake blocks. Casual failures include draw bars and springs, axle box springs (usually volutes or spirals), brake lever links, pins and screw nuts, and the usual wear and tear of injectors, boiler taps and gauges. A stock of these parts is of course kept, and spare sets of wheels and axles, tyres, &c., ought to be available at any time. Worn tyres are turned down two or three times before they are discarded.

Tram cars are, as a class, far better specimens of careful design than any other class of road vehicles. They are light, strong, comfortable and airy. The underframes are, of course, chiefly within our province. In a general way the greatest fault is the shortness of the wheel base, which causes the cars to pitch and rock, throwing the weight from one axle to the other. This can only be got over by employing swivelling bogies. In America this is done to some extent, and the effect in easing the traction and steadying the car is most marked. The design of wheels, axles, axle boxes, horn plates and springs is good, and might be copied with

advantage by omnibuses, &c. The wheels are usually of cast steel, in one piece, and therefore when the tyres are worn are renewed entire. The axle boxes and brasses are of the usual railway type (see p. 339) and call for no special mention. The springs are either single or double volutes or spirals, and in a few cases of rubber, or rubber and a spiral combined. The draw bars and pins sometimes break, but are simple forgings, easily renewed. The brake gear and foot catches or ratchets and pawls for holding the brake on, of course wear a good deal from incessant use, as also the screws and nuts. Brake shoes are generally chilled castings, or of white cast-iron. There is nothing in the repair of these that requires special mention. The various tramway companies have their own repairing shops, and keep all wearing parts in stock for immediate use.

CHAPTER XXXII.

RAILWAYS. PERMANENT WAY.

TO deal effectually with these would require a large volume, but, following out the lines of this work, we propose only to consider them in the light of questions of maintenance and repair, dealing only with design and detail, as bearing on these practical points.

Maintenance and repair are factors entering very intimately into the economy of a railway system, and, in fact, are the two spending or losing departments which every company does its best to keep at a minimum, and for this end the construction of its rolling stock is designed, and upon its efficiency in these matters to a large extent depends its financial success.

The general wear and tear on a railway falls upon the rails, switches and crossings, locomotive and carriage wheels, axles, axle boxes, brakes and draw bars. Besides these we may class as casualties the breakages of fish bolts and plates, draw bars and hooks, buffers, springs, axles, tyres and other

details. There is a third class also, in which we place deterioration from oxidation, rotting of wood sleepers and carriage wood work, corrosion of exposed iron work, decay of paint and other external surfaces, and perhaps a fourth class, which includes smashes from accidents of all kinds.

Wear and tear can only be kept at a minimum by employing the best possible materials to meet the inevitable wear, and by keeping down the sources of wear as far as is possible. These include vibration, friction of running parts in contact, as wheel tyres and rails, axles and brasses, brakes and tyres, &c. Vibration is avoided by a thoroughly well laid permanent way, and by effectual springing of every axle in proportion to its load, and of each draw bar and buffer. The friction of running parts is only partially met in the case of axles by a thorough system of lubrication, but wheel tyres cannot be lubricated, and though they wear slowly on the "tread," they wear fast on the flange where there are many curves in the rails. The principal source of wear, however, is due to the brakes, which wear the rails, tyres and brake blocks. Friction, which is the essence of braking, cannot be had without a corresponding amount of wear or abrasion.

Casualties result from many causes: expansion by heat; continual vibration, causing crystallisation; over tight screwing up of bolts; loose bolts; careless jerking in starting a train into motion, or collisions from engines and trucks in the stations in shunting; running off the rails; points and crossings; obstructions, and also defective material or workmanship.

Deterioration and decay are inevitable to a great extent. Outside ironwork invariably suffers from corrosion—paint and galvanising may do something in remedying this source of loss. Wood sleepers are very badly situated for long life; creosoting and tarring protect them to a certain extent, and careful selection of timber and seasoning does something more, but the loss from this source is so great that many attempts have been made to introduce iron, the chief objection to which is want of elasticity; a rigid permanent way ruins the rolling stock, and so one source of loss would be reduced at the expense of introducing another and more

expensive one. Wagon and carriage woodwork decays from the weather effects upon joints, under iron plates and straps, bolt holes, &c., as at these places the water gets in and rots the wood.

Collisions and accidents of all kinds cause heavy losses in rolling stock, besides the loss of life, as engines and carriages sometimes become mangled almost beyond belief, and generally beyond the possibility of repair. A couple of engines ruined, and half a dozen carriages smashed, means a money loss of 10,000*l.* or more, a sum that would pay for repairs to the two trains for 50 years.

To treat these subdivisions in greater detail we will refer now to each wearing part separately, and the best means of repairing it and of keeping it in repair.

The Permanent Way.—A well laid and well drained road bed is of the greatest importance for maintenance of the rails in good order. Settlements and bad drainage tell largely upon the life of sleepers, chairs and fish plates, besides inducing rough travelling in the rolling stock. The road bed, therefore, should be solid and firm and of a material that will not retain water: gravel, chalk, flints, clinker, slag and similar materials are the best for this purpose. Next in importance is the regular examination and packing up of every sleeper, fish bolt and chair, by platelayers accustomed to this work. Crossings and switches need special attention, as they naturally take the brunt of the hardest usage, and are sources of the greatest risk; the blows they receive and their disconnected construction tend to produce looseness and displacement. Wooden keys shrink and drop out in dry weather and therefore need frequent knocking up, and spikes and treenails work loose from similar causes. Expansion in hot weather and contraction in cold weather cause the rail joints to close up and open again, and keep the fish joints constantly moving in and out. Sufficient attention is seldom given to the superelevation of the exterior rail on curves, so that considerable strain and wear is induced on these outer rails by the centrifugal force of motion of heavy trains. Coning the tyres does little to prevent this, but is always desirable, as it keeps the train in

the centre line, but on curves it causes a good deal of slip on the inside wheel, as the outside wheel is then running on a circle of larger diameter than the inner one, and has the greatest bite of the rails, this causes skidding or slip; but in any case a mere approximation to the differential diameters and speeds is all that could be obtained in this way. Further than this, the axles and wheels on curves, instead of running radially by some swivelling device, are out of square with the rails and thus tighten up the guage and bear hard on the inner edge of the outer rail. The bogie system, as adopted universally in America and partially in this country, is best calculated to minimise these faults.

Steel rails are now universally used, and are at least 100 per cent. better than the best iron ones previously used. It is doubtful in fact if any better material can ever be produced; the qualities of steel are now so thoroughly good and so much under control that we anticipate very little improvement in this direction for a long period. A light section of rail is known to be poor economy, the actual section used should be dependent on the weight of engines and rolling stock. The gradual increase of the weight of these of late has caused the introduction of very heavy rails, and the general strengthening of all bridges, &c., so that where a 56 lb. rail was formerly used, rails of 90 lbs. are now common, and the weight of engines has risen from 20 tons to as much as 45 tons. The bogie system of carriage construction also increases the load on each axle, and therefore the load on the rails. The sleepers and chairs are also fixed closer together than formerly.

Fish plate bolts are now generally provided with some sort of spring washer or other device to prevent loosening, which devices are, however, only partially effective; the heavy blows and vibration to which they are subject will loosen any fastening that admits of it. There is still room for a reliable bolt for this purpose.

Steel dished or hollow sleepers have made very little progress in this country, but are used abroad, where timber is costly, or where lines are to be laid either temporarily or

with unusual rapidity, and they are effective in every respect except that of want of elasticity, which must, however, be considered as absolutely essential on passenger lines. Fir and oak are still used almost exclusively. Oak is better than fir in the proportion of 1·75 to 1: it holds the spikes better. The chairs also do not compress the wood so much as in fir.

Spikes should be straight, chisel pointed, driven in across the grain, and the holes for them bored quite through the sleeper, one-half the diameter of the spike.

Bridge or flanged rails with longitudinal sawn sleepers scarfed at the joints, and with cross tie-bolts and timber cross struts, form a very good line, but are not so easy to lay as cross sleepers. The lengths of timber also warp and are rarely straight, so that a good deal of thin wood packing under the rail is required to level up the rails. This plan, however, avoids chairs and keys, the rails being spiked down by hooked spikes and fished by a plate laid under the joint, which, however, is not so good as the side fish; but, on the other hand, the rail when worn cannot be reversed as the double headed rail. On the whole, therefore, we conclude with the majority of the railway companies that the cross sleeper plan is still the best all-round plan, one important reason being the greatly increased area of bearing of the sleepers on the formation.

Switches and lever gear require regular attention and oiling. The pins, centres, bolts, &c. need to be secured by split pins or other means of preventing loosening; single nuts or lock nuts must not be depended on. The ordinary detached construction of switches would be greatly improved by a system of gusset or foundation plates, to which all the rails of the crossing were riveted into a complete frame. This would make a sound and serviceable work, and give no trouble from looseness, besides being cheaper in the end. All levers and bell cranks must be set to work in line with the rods, and also at right angles when at half stroke; and protected by boxing so that the gear cannot be jammed by accidental obstructions. Wire movements are unsatisfactory and are giving place to rods and guide rollers. Gas tube, L, T, H, or channel iron are all used and useful for these rods, being cheap, stiff, light

and easily scarf-jointed. The rollers, however, are commonly made much too small in diameter to work freely, and ought to be protected from rains by a cover.

Messrs. Saxby and Farmer have introduced a very efficient guide roller, having slot bearings in which the roller spindle rolls horizontally.

CHAPTER XXXIII.

CARRIAGES AND WAGONS.

Wheels and Axles.—A good many varieties or types of railway wheels are in use: each has its advocates, and no doubt each has its advantages. We find, however, that few companies will go far away from the standard type of a cast boss, wrought-iron arms and solid steel tyre. There is only one form that, we think, will eventually displace this type, viz. the steel dished form made in dies by hydraulic pressure. This is undoubtedly a simple, very strong, reliable wheel body, and is already much used for tram traffic, but will not compete in cost with the old composite type. In America cast-iron wheels chilled on the rim are much used, but are very insecure and wear out rapidly. Solid wood webs, with steel tyre and cast boss, are much used for passenger coaches, and give good results. In these the tyres are secured by rings on both sides, riveted through the web. There is nothing elastic about a railway wheel, which, though it is provided with good springs above the axle box, still, from its own weight and consequent inertia and rigidity, sustains a deal of hammering at the joints and crossings that undoubtedly has a good deal to do with its wear and tear. Otherwise its wear is chiefly due to friction of the flange against the rail head, friction of brake blocks, skidding on the rails, which causes flats on the tyre, and friction due to skidding and centrifugal action on curves. New tyres therefore constitute a considerable item of expenditure. They are put on hot so that their contraction when cold is in itself

almost a sufficient security; but in addition countersunk rivets are put round with long heads (as Fig. 316) to secure the tyre to the rim or curved arms. Steel tyres are now rolled with great accuracy, both as to roundness and diameter, and being formed without a weld it is difficult to see how any better or stronger tyre can be manufactured. The rivet holes are undoubtedly a source of weakness, and many suggestions have been made to avoid them, but none of them are in practical use except the Mansell tyre (Fig. 317). Some such method as Figs. 318 and 319 would be effective if executed while the tyre is hot. In this plan the tyre is rolled with a lip on the flange side, which is caulked, hammered or rolled down to close on the bevelled edge of the rim. Axles occasionally become bent so that the wheel rim is out of truth. Every

Fig. 316.

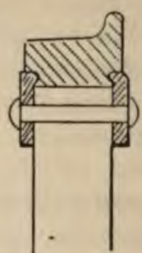


Fig. 317.

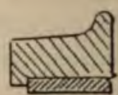


Fig. 318.

Fig. 319.

axle sent in to refit should be tested for accuracy and straightened, after which the journals should be skimmed up in the lathe or the axle will probably run hot and soon wear out the brasses. Some little end play is usually allowed in the bearing, besides the springing of the horn plates and play of the axle box itself, so that end tightness seldom occurs. The wheels are fixed on the axle by shrinking them on hot and keying them up when cold; a rail gauge is used to adjust them to exact gauge, the clearance commonly allowed being $\frac{1}{2}$ inch to $\frac{5}{8}$ inch, or, where there are sharp curves in the line, as much as $\frac{3}{4}$ inch is allowed.

To take off old Tyres.—After cutting out the rivets, the tyre is heated by a ring of gas jets or a ring furnace. Where a foundry exists, they can be set horizontally in the floor sand

and some hot metal run around them; a good heat is obtained this way, and in a few seconds they can be got off without trouble. New tyres can be expanded the same way, the wheel dropped inside them and cooled off.

Axle boxes are of cast iron, occasionally of steel, and provided with an upper brass only, grease well and cover. It is not at all certain that the system of lubrication by grease is a sound one, and oil is now being much used. The axle gets no lubrication at all until hot enough to melt the grease, and in other respects does not fulfil the well-known laws of lubrication, for it is well understood that the thickness or viscosity of a lubricant should be greatest with the greatest pressure per square inch on the journal. Grease, when melted, is only oil, and the actual pressure on a wagon axle, loaded, being about 3½ tons, distributed on a journal about 8 inches by 3 inches, gives 327 lbs. per square inch, which is nearly the pressure commonly allowed on shafting and engine bearings, which are lubricated well with a moderately thick mineral oil, so that it would appear that a similar method of lubrication ought to be effective with railway axles. Mr. Tower's experiments show that a maximum of 625 lbs. per square inch may be employed before heating takes place. The latest types of axle boxes, therefore, have an oil well for mineral oil, and are provided with leather dust shields, and automatic means of raising the oil on to the journal when running.

The brasses of course wear badly, are rarely machined to the journal, being commonly put in just as they come from the foundry, and are as often allowed to run till the axle cuts them in two and begins to bear against the axle box. A good hard quality of bronze cast from new metals is best for axle brasses, but they are often cast from all sorts of scrap, as a result of competition in prices.

There is no doubt that better attention to these matters would effect some economies in railway maintenance. There is, in fact, no reason why railway axles should not be as efficient and lasting as any other kind of bearing. Roller and ball bearings have been proposed from time to time, but cost and complication stand in the way of their adoption. Con-

sidering that the friction of the axles is the chief resistance to motion of a train, it seems to follow that any percentage gained in this direction is, in effect, a percentage of power of the engine saved, and is certainly worth all the attention that can be given to it, and some cheap and simple form of roller bearing might be devised which would save a great deal in lubricant, tractive power and wear of brasses.

Brake Gears.—On ordinary wagons these consist of wood blocks pressed against the wheel by a lever and link, keyed upon a rocking shaft provided with a long foot lever and ratchet rack to keep it "on" until released. The whole affair is roughly made, and its defects are (1) its scrooping noise, loose jointed construction, and wear of the blocks; (2) the side strain put on the axle boxes. The noise is extremely unpleasant—if familiar—and in the neighbourhood of houses is most objectionable. The side strain injures the bearings by wearing them out of truth. This ought to be remedied by making the brake double, so as to grip the wheel without cross strain on the axle, or else a single block applied on top of the wheel.

The old method is unmechanical and expensive. Cast-iron blocks are now replacing wood ones to a great extent, with the advantage of less noise, but no great saving in cost. On passenger coaches the double brake is absolutely necessary, and, in fact, always used on good lines. It has the advantage of gripping the wheel on both sides without straining the axle when the pressure is equally applied, which is not always the case.

Atmospheric brake gear of both pressure and vacuum types has been introduced, and is now almost universal on passenger trains. The pressure or vacuum is maintained in strong steel reservoirs under each carriage by a small engine fixed on the locomotive. The whole are coupled by flexible hose, with a special union between the carriages, and the guard or engine-driver can instantly apply the brake to every wheel in the train. The troubles incidental to these gears are chiefly due to leakages, bursting of pipes or joints, failure of valves, and fractures of levers, &c., from the suddenness with which they

are forced in gear. Every detail is, however, being gradually improved as the result of experience and failure in the past, so that such accidents are now comparatively rare. The valves need frequent grinding in or renewal. The joints are made with rubber insertion manufactured to the shapes required. Sphincter-grip hose is used for the flexible connections, and a special very simple knuckle union with rubber joint, which is coupled or uncoupled by a single movement.

Springs and Buffers.—The amount of buffing and of elastic bearing allowed on the axles varies with the class of vehicle; from the coal and mineral wagon with neither axle, springs nor buffers, or with axle springs only, to the modern Pullman car, with long sensitive axle springs, long buffer and draw bar springs. Considering the rough treatment to which mineral wagons are subjected, especially in shunting, with no buffers to break the shocks, it would certainly pay to add stiff spring buffers to this class of wagon, as also draw bar springs, for the fractures of draw bars and hooks are very numerous from want of elasticity, and the framing and body of the wagon soon get knocked to pieces. The annual cost of repairs amounts to from 4*l.* to 8*l.* per wagon.

Flat laminated plate springs are, generally speaking, less liable to fracture than any form of spiral helical springs. Double helical and volute springs are much used for buffers. In spring making, however, assuming the use of a suitable quantity of steel, the whole depends on the tempering, and most failures are due to unevenness in temper, from the difficulty of heating them to an even temperature, and then the further difficulty of cooling them evenly. A plate spring is easier to temper than a spiral, helical or volute. A metal bath is the most certain method of heating, but cooling is not so manageable, as the edges and ends get chilled before the middle parts, resulting in uneven strain or temper, and sometimes cracks; such failures are generally set down to bad materials. The breakage of a spring does not, however, lead to more serious accidents as a rule. In the case of laminated springs, they rarely break altogether, usually one or perhaps two plates give way, and the others become bent

or crippled, but with spirals and volutes, if they break, they of course double up entirely. Rubber would be effective if used in large enough pieces or washers, and has been used to some extent, but unless of first rate quality, soon cracks or crushes out of shape or gets hard and indurated. Oil or grease also will rot them into a paste.

Axle springs should have perfect freedom of play, which is difficult to apply to any but laminated springs, as the pressure on spirals, &c. rarely is truly central. Laminated springs can, however, be hung by links at each end to the car frame, so as to move freely. Rubbing plates are not so good, the pressure causes so much friction that they drag and are lacking in freedom.

Draw bars and hooks.—Notwithstanding very numerous and ingenious attempts to improve the draw bar attachments of carriages, to prevent the accidents resulting from the practice of coupling and uncoupling from between the vehicles, the old hooked bar seems to still maintain its hold. In America, several patent self-locking hooks are in use, but little can be argued as to their efficiency from this fact, because everything in that country is in a state of transition or evolution, and nothing finished. In England, we move more slowly, but very surely, and though we have tried the same devices have not adopted them, as lacking some element of permanent usefulness. Undoubtedly, however, some means of coupling from the outside is highly expedient, otherwise there is very little can be urged against the chain and hooked draw bar. They sometimes break, chiefly because they are hand forged and cheap, but would be much better drop forged or pressed in dies. Good springs to the draw bar prevent many breakages, however, and save the wagons also from much jar and shaking. Broken hooks should never be welded up again, nor should there in any case be a weld in the hook or its neck.

In carriages the chain is supplemented by a tightener, a right and left-hand screw, lever with ball-weight and two nut shackles. This is an effective though rather expensive device, and has the demerit of throwing all the strain on the screw,

which must be of large diameter to maintain an effective sectional area. But screws are notoriously faulty, because in cutting the thread, all the best metal is removed, and the square angles left become weak points in the remaining section of metal. It is important, therefore, where threads are cut, that the section of metal remaining is at least 20 per cent. in excess of that of the plain bar.

Framing and Timber Work.—There is now a movement in favour of the introduction of metal underframes, to entirely replace wood, and it is evident that the change will come about in time. Wood has the disadvantages of shrinking with drought, swelling with wet, and cracking or opening along the heart, besides which it is impossible to make such rigid and stable connections of parts as with iron or steel. Bolts work loose in wood, rivets and screws get loose from shrinkage and corrosion. Every hole and joint is a source of deterioration and rot, the joints at angles also are soon loosened by constant straining. None of these defects exist with iron structures except corrosion. Riveting makes a most firm and durable joint, unaffected by vibration. Iron wagons and iron underframes for carriages can be made as cheaply and as light as wood, and only need attention to painting to give them at least twice the durability of the latter.

The maintenance of wagons depends largely on early attention to defects. Too often they are allowed to run till a small repair becomes a large and costly one. Periodical tightening of bolts is of great importance, especially in summer time, when every bolt that passes through woodwork is liable to become slack. All straps, knees, angle plates, horn plates, and other fixtures, must be tightened up periodically, and straightened or repaired when bent or damaged. Flap doors and the openings in wagon sides, hinges, &c., are very liable to injury and displacement. The floors commonly require renewing two or three times before the underframes, and the latter generally become rotten from leakage through the wagon floor. Tongued flooring would do something to prevent this, and a thick coat of tar or pitch should be laid on the upper side of the timbers before the floor is laid down.

Oak is the best wood for framing. Red pine is commonly used for sides, and elm or ash for flooring.

Covered wagons or box wagons wear much better than open ones, because the weather is excluded, and carriages wear better still for the same reason, and because they are well painted and varnished, and the joints are more perfect throughout, so that wet can find no entrance. The exclusion of the weather is therefore of the greatest importance, by the use of plenty of paint and attention to keeping all joints tight.

Bogie frames or swivelling bogies are usually self-contained wrought-iron or steel-framed under-carriages, with four wheels of smaller diameter than ordinary carriage wheels, and placed close together. The carriage body rests at each end on a centre pin or swivel frame, and the bogies swivel in passing curves to the radius of the curve, whereas ordinary carriage wheels do not swivel, and therefore are out of square in passing round curves, causing a good deal of skidding and grinding between the wheel flanges and the rails, chiefly on the outer rail. This error is thus greatly reduced, though not eliminated in the bogie truck. The most improved designs of locomotives also introduce the bogie truck in front for the leading wheels; it would, however, be almost impossible to apply it to the drivers, as this would necessitate a varying length of connecting and side rods. As there is a tendency to increase the length of carriages, the introduction of the bogie mounting seems inevitable; they will turn very sharp curves with safety, and where a uniform or standard type of bogie is adopted it is easy to exchange a damaged one in a short time for repair, without detaining the carriage. It is not desirable, however, to reduce the diameters of the wheels. For high speeds, in fact, it is absolutely necessary to have large wheels, and it is quite possible to maintain the diameter with a well designed bogie. The swivel centres and races ought to be always run on rollers or balls to reduce friction.

CHAPTER XXXIV.

LOCOMOTIVES.

THOUGH there are many hundreds of designs in use, they vary only in matters of detail, and the reader is referred to such works as D. K. Clark's 'Railway Locomotives' for designs and details of the leading types in existence. Until recently very little attempt was made to study economy of fuel consumption in locomotives, but now compounding, higher pressures, improved valve gears and furnaces are being largely employed to reduce the coal bill and increase efficiency, as also to increase power in proportion to weight. Heating the feed water, regulating combustion, balancing the slide valves and utilising the exhaust are sources of economy still scarcely touched upon, though carefully studied in stationary engines. These will, no doubt, receive attention before long; the conditions of successful working on railways are becoming largely dependent on economies such as these. But any improvements that might tend to affect speed, simplicity, free starting and add useless weight, or in any way operate as possible sources of accidents or delays, cannot possibly receive consideration, and no doubt the difficulties in the way of their successful introduction without these drawbacks have been the causes of postponing economic improvements that have long been considered essential in stationary engines.

In general design a locomotive consists of a boiler and furnace, a framework, a set of wheels, axles and springs, and a double-cylinder engine, to which are added water and fuel receptacles, a foot plate or "cab" for the driver and stoker, brake appliances, rail sanding apparatus and the usual fittings of an engine and boiler, specially designed, of course, as indeed are all the details.

The history of the evolution of these essentials from early crude, though undoubtedly clever types, is an exceedingly interesting one, and was well illustrated at Chicago; and it is

remarkable that compared with other types of engine the differences between those of to-day and of 50 years ago are comparatively small. Still every detail has received a vast amount of care and thought, with abundant evidence of experience, so that at the present day the types in use rarely deviate from certain well established rules. The changes taking place are chiefly in the introduction of bogie underframes, compound cylinders, improved reversing valve gear and air brakes.

We are not concerned with special features of design, but propose to consider the general details in relation to their repair and maintenance chiefly. Every railway company has its own repairing shops, and in many cases its own building shops also, placed at convenient points in its line of communication. At terminal stations also, it is customary to have appliances to deal with casualties and to overhaul every engine that comes into the station ; cases beyond these local resources are of course sent to the repairing works. The drivers and stokers are also provided with such tools as they can use on the road, and at all stations screw-jacks, drilling tackle, &c., are kept ready. Many locomotives, in fact, carry a screw-jack on board, usually a traversing one.

Locomotive boilers do not differ materially in general construction from those of agricultural and traction engines. They are, however, better mounted by rigid wrought-iron plate work attachments to the engine framing. This must be done in such a way as to allow for expansion by heat, otherwise straining and leakage will occur at the rivets. The underside of the boiler is usually very difficult to get at, being crowded with gear and pipe work ; longitudinal seams should, if possible, be made at the sides or top, and ring seams placed where they are always accessible and not covered by cylinders or other fixtures. Neglected leaks from seams or fittings of course lead to external corrosion, especially at joints, attachments to fittings, blocks, &c. The principal source of failure is, however, almost invariably the fire-box. The best are of copper, but these are expensive, and we find that Yorkshire iron or mild steel are much used ; a boiler

will generally have two or three new fire-boxes before the shell gives way. The tubes require frequent cleaning and sometimes caulking or expanding at the end, the leakages from these being the most fruitful source of corrosion of the fire-box; but, considering the number of stays, crown stays, tubes, &c., and the variety of antagonistic strains these introduce, it is only remarkable that this type of boiler does so well. In fact, some other form of fire-box is highly desirable, and like the old box form of marine boiler, will be replaced by a simple cylindrical tube, especially as the pressures used are greatly increased, and with the compound engine will, no doubt, be still further raised in the near future.

The internal steam regulator valve is another ancient detail and requires putting outside the boiler (see p. 87). It is really marvellous how such palpably inaccessible and dangerous fittings ever got where they are.

The longitudinal seams are usually double riveted, and all rivet holes drilled. The rivets are best closed by a hydraulic riveter, whose steady pressure is greatly superior to blows with hammers, especially with mild steel rivets. It is of course almost impossible to make a multitubular boiler accessible for cleaning, and in this respect the locomotive boiler is but on a par with the common portable or traction engine. The quality of the water along any line of railway varies a good deal, and the engine driver has only his blow-off and mudholes to keep his boiler clean. The tubes are invariably placed so close together and in zigzag order, that there is no chance of getting a scraper between them. It is usually assumed that all the sediment will settle round the fire-box water space, this being lower than the bottom of the barrel of the boiler, and no doubt most of it does get there, and if not frequently cleaned out will fill up above the fire-bar level and soon cause burning of the lower zone of the fire-box plates. A really accessible boiler for locomotive purposes has yet to be designed. At present everything is sacrificed to quick steaming and heating surface.

For general notes on repairs see Chapters I and II.

Framing.—The framing is of wrought-iron or steel plate, and usually each side is cut out of a single plate by a slotting machine. These side and cross plates are stiffened by L irons and carry most of the engine details, cylinders, wheels and axles, boiler, buffers and beam springs, pump, foot plates, &c.; none of these ought to be attached to the boiler, which should be free to expand and contract without restraint. The framing rarely suffers injury from wear or even corrosion to any great extent, and usually outlasts the engine, unless smashed in a collision or other accident.

Such details as funnel, blast pipe, blast nozzle, sheet iron lagging, and the wood and felt filling underneath, need periodical renewal, as they get destroyed in time by corrosion, rain and heat, and on these occasions a general overhaul and repainting usually take place.

The steam cylinders of locomotives, and in fact the running gear also, do not materially differ from those of ordinary horizontal engines. They suffer, however, from exposure to the weather and to considerable vibration in running, and it is usual to make all such details stronger than those of ordinary engines. Some attempts have been made to use piston valves in place of the D slide, but they are unsatisfactory because of difficulties with the packing rings and ports. A simple balanced slide valve, easily repaired and with faces easily renewed, is much wanted. Some of them are partially balanced by a packing ring on the back of the slide, working against a planed face on the valve chest cover. As in other engines, the cylinder and valve lubrication are very uncertain and unsatisfactory, and in consequence the internal wear is very heavy. It is quite a common thing for a locomotive to require its valve faces renewed or refaced two or three times a year, and of course cylinder boring and gland renewing or bushing follow in proportion. A thorough and regular lubrication would prevent much of this, but it must be automatic, as the driver has no time to give it the frequent attention it would otherwise require. A further cause of wear and tear is the large amount of dust and road grit that constantly overspreads the running gear. It gets

carried into every moving joint and bearing with the oil and causes cutting and grooving. It is difficult to see how this can be avoided, for if we succeed in shielding the bearings—as is, in fact, to some extent effected in the main bearings—there are still the guide bars, piston rods and numerous joints that can only with great difficulty be protected, and the complication and boxing up that this would necessitate would be a greater evil than the present loss. Considering that a locomotive has to encounter rain, sleet and snow, dust, sand, smoke and ashes at different times, and one or the other almost continuously, it is not remarkable that its bill for repairs should be a long one.

Two methods of boiler feeding are usual, by pump and by injector, and every engine should have two feeds. In some the pump is worked off the crosshead, or by a separate eccentric—the latter is best, as the stroke and piston speed is much less than the former — others have an independent donkey pump, which has the advantage that it can be used when the engine is standing; so also can the injectors. Injectors are, however, rather tricky and troublesome, and when out of order frequently beyond the powers of the driver or stoker to put right, so that it is not at all safe to depend on injectors only; slight chips, wear of nozzles, variations of steam pressure, temperature of feed water, all tend to make them uncertain in action. Pumps worked from the crosshead give a deal of trouble also from the long stroke and speed and the hammering of the valves. There is a good deal of slip with them from these causes, and in consequence they are now seldom used.

The rams, packing and glands of course get much grooved and worn; the pipes and joints are also sometimes burst by the hammering action of these pumps, besides which the side strain on the crosshead is very objectionable. Pumps worked by eccentrics or by a short throw of the crank are larger in diameter, shorter in stroke, and from one-third to one-fifth the speed of the crosshead type, and the troubles connected with them are reduced in a similar ratio.

Donkey pumps have been treated of in Chapter VI.; they

have their faults also, but in this case they have the advantages of greater accessibility and ability to start at any time with a few pounds of steam to fill up the boiler. They can also be stopped when not wanted, instead of running all the time as engine pumps do; this saves a great deal of wear. At the same time we must not overlook their faults, which are rather numerous. Though faulty, however, as they often are, there is still the merit of accessibility and absence of complication. Any decent engineer can keep his donkey at work even when in a bad state of repair; besides which they do not break down suddenly like injectors except on rare occasions, but give fair warning when they are going wrong.

Running Gear.—In the locomotive there are, in addition to the ordinary piston rod, connecting rod, crank shaft, eccentrics and valve gear, a long reversing motion worked from the foot plate, and a system of side rods or coupling rods. The motion is further complicated by the rise and fall of the driving axle against its springs, and by the end play sometimes allowed to one or more pairs of the coupled axles. The joints, stub ends and crank pins are therefore required to be strong and well fitted, allowing for the variations introduced by the elastic movements of the axles. Solid end rods are in general preferred as safer than strap ends, and where the latter are used they are secured by bolts and joggles so as not to depend on the gibs and cotters alone. In the side rods the brasses must be taken up so as to keep the centres to dead length; this is best done by setting the crank pins at the dead centre, as at this point any defect in length would cause jamming.

Every cotter and key must be secured by a set pin or split pin. Keys and wheel or lever bosses need to be unusually well fitted on account of the speed and vibration to which they are subjected. The inaccessibility of a locomotive running gear is a source of trouble and risk. Very little can be done in the way of examination and close adjustment except with the engine standing over a repairing pit. Improvements may perhaps be possible in this direction, but it is difficult, with the present design, to suggest alterations. The French method of putting

ll the valve gear outside the wheels, with its crank pin ccentrics and complicated valve motion, is not tempting to us o copy; it seems to involve greater risks than it eliminates. Raising the boiler has done something towards opening up he gear to view. Boxed up, enclosed, or inaccessible gear is lways a source of risk and anxiety, and should be avoided. Repacking glands, adjusting guide bars or crossheads, conecting rod brasses and other adjustments are difficult to do ınder such circumstances, and therefore apt to be neglected.

In the running shed every engine is supposed to be overıauled every night or day as the case may be, and these ıdjustments attended to, so that the driver has little to do besides use his oil can when on the road. A further opening or improvement is the provision of better means of getting ound the engine in safety when running. To hold on by a ail with one hand while standing on a slippery foot plate, and ıse the other about some necessary job at the side or front of he engine is neither safe nor pleasant as these things now re. Of course men can be trained to it as to any other ifficult feat, but it does not strike one as being either necessary r desirable; the accidents that often result are proof of this.

Certainly more attention is now bestowed on the comfort nd security of the men than was formerly the case, and will esult in greater safety to the traffic generally.

Cleaning is an important item, and should be regularly and horoughly done; it is surprising what an amount of dirt, rease, mud and soot accumulate all over the engine, especially n bad weather. Some of this must, of necessity, find its way nto the bearings and guide surfaces, where it prevents the oil rom doing its duty. The boiler tubes must be frequently craped, or the steaming power of the boiler will be greatly educed, while the coal consumption will rise in proportion. Leakages at the safety valves and past the slide valves run way with a good deal of steam.

Repairing has been generally dealt with under the heads f Steam Engines (Chapters IV. and V.), Portable Engines Chapter V.) and Traction Engines (Chapters V. and XXXI.) nd most of the details there treated of apply equally to

the locomotive. There are, however, some few details of the latter, peculiar to itself, which may be mentioned here. It will be found in the locomotive that the brunt of the wear and tear fall on the *main bearings* and axles, tyres, horn plate guides, link motion, *connecting rod and side rod brasses*, guide bars and *crossheads*, pistons, piston rods, *slide valves and faces*, valve rods, glands and necks, valve rod guides, feed pumps, eccentrics and *straps*, those marked in italics getting the severest wear.

The horn plate guides are almost invariably provided with adjustments for wear, and it is important that these axle box guides should be good fits, especially on the driving axle, otherwise "knocking" occurs and results in loosening and hard wear of the brasses. These guide faces should be planed true when the wear becomes considerable, and at other times may be scraped and filed.

The guide bars and crosshead also have provision for adjustment and renewable faces to the crosshead, as a rule; the bars in course of time become worn hollow, and must be planed or renewed, as at this stage no adjustment will relieve the trouble. There are several types of guide bars and crossheads in use; the latest form, which seems to be much favoured now, is a heavy single bar, with encircling slipper crosshead; it is certainly simple, and if made long enough, effective; if too short they wear most at the ends and this gives rise to springing of the rod; but these bars are not easily lubricated.

The crosshead centre pin often wears badly, becoming oval and badly cut; it ought to be turned partially round at short intervals, to equalise the wear and maintain a fit to the brasses.

The wear of piston and valve rods, glands and necks, depends much upon the efficiency and condition of the guides and centres; and secondarily on the quality of the packing and lubrication. Gland lubricators are desirable and in general use, but not always efficient.

In the running shed the engines are generally handled by screw-jacks over a repairing or "blow off" pit; but in the repairing shed much greater expedition is attained by using an overhead traveller for lifting.

Section VIII.

MACHINE AND HAND TOOLS AND WORKSHOP MACHINERY.

CHAPTER XXXV.

SMITHY PLANT AND TOOLS.

This section comprises a very large and varied class of machinery for dealing with manufactured metals in the production of machinery and metal work of every description.

In an engineer's works—consisting of a pattern and wood shop, smithy, foundry, boiler yard and engineer's or machine shops—a very extensive variety of machines will be found, which, with a few exceptions in matters of detail and size, is universally the same all over the world.

These comprise, in the pattern shops, wood turners' lathes, band saws, circular saws, moulding, tenoning, mortising and other wood working machines, which we shall refer to under wood machinery (see Section IX.). In the smiths' shops, steam hammers and forging machines. In the foundry, blowers or fans (see Chapter XIII.), overhead and swing cranes, and foundry ladles, cupolas and utensils generally. In the boiler works, punching and shearing machines, drilling and riveting plant, plate edge planing machines, hydraulic flanging presses, plate bending rolls, cranes, bending blocks, pumps and testing appliances. And in the machine shops, lathes, planing machines, shapers, drilling, slotting and milling machines, screwing machines, emery and stone tool-grinders, cold saws and various special tools designed for particular

specialities, besides the usual stock of vices and other hand and small tools generally.

Many machines may be said to possess several features in common, and contain details such as guide beds, reversing motions, speed gears, traversing screws, tool boxes and the like, that are practically alike in all cases. The motive power, engine, boiler and shafting, have already been treated of (Chapters I. to VII. and XVIII.).

The whole may be divided into classes, viz. :—Revolving tools and reciprocating or right line tools. Under the first class come lathes, drilling and boring machines, screwing and milling machines, emery and other grinders, and cold saws. The second class comprises the planing, shaping and slotting machines.

Passing over the pattern and wood work we come first to the smithy. In most engineers' works this department is one of the least satisfactory, because the work is, as a rule, irregular, unless forged specialities are on the books of the firm; the cost is often out of all proportion to the estimates, a great deal of time being spent frequently in rigging up and preparation for jobs which take but little time to execute when the "rig" has been provided; and from the fact that a great deal of time of both smiths, strikers and fitters is spent in repairing tools and odd jobs that cannot be directly charged to customers. Smiths also, as a rule, are very unlearned in reading drawings, and it often pays to provide them with wood patterns of the articles wanted, otherwise many wasters and misfits result from misunderstanding, and from overlooking needful surplus metal to allow for machining, where required.

The machinery used in a smithy usually comprises steam hammers, plate or bar bending machines, fans or blowers, punching and shearing machines, and cold saws. There are also the smiths' fires, anvils, vices, tongs and other tools, and sometimes forging machines for nuts and bolts, but these are now specialities and rarely found in an engineer's works.

Steam hammers are of numerous patterns, and in some instances replaced by atmospheric or power hammers, stamps

and steam strikers or "Olivers." They range in power from a few pounds to many tons. It is generally known that light hammers expend their blow on the surface of a forging without penetrating deeply, while a heavy hammer affects the whole mass of a forging, altering its entire form at every blow. In works of any extent, therefore, two or more hammers are required, to give that variety of weight and velocity necessary to the numerous and varied shapes and sizes of forgings produced.

Every steam hammer, whatever its special features, comprises a cylinder and piston, piston rod and hammer head, starting valve and lever, standard and anvil. Some cylinders are single acting only, that is they lift the hammer by steam pressure but exhaust at any height required, letting the hammer fall by its own weight. Others add the pressure of steam on top of the piston to give force to the blow, and these usually have small hammer heads and are often guided only by the stuffing box and piston. These are provided with a very thick rod which serves to add weight and stiffness to the hammer head, and at the same time saves steam, the annular underside of the piston being only sufficient to raise the hammer, the larger, full area on top giving full power for the blow on the down stroke. There is very little to find fault with in the steam hammer. It is not worked so incessantly as a steam engine, consequently the wear is much less. Its casualties generally result from loosening of parts by the blows it strikes, and some trouble is experienced in securing the hammer head to the rod (Fig. 320 shows one method commonly used) and the hammer face to the head. Unguided hammers are often injured by striking out of line, that is to say, on the edge or corner of the hammer head (Fig. 321), for which reason the faces should be small. Good fitting is essential in the dovetail or other connection of the steel face to the hammer head. Two methods are shown, both requiring cotters and good fitting of the base of the rod to the hammer face.


FIG. 320.

Guided or dead weight hammers have smaller piston rods, and these frequently jar loose and give trouble in consequence. The best methods of attachment are shown in Figs. 322 and 323; screw and nut attachments are of no use to stand the vibration. These joints must be well fitted and the end of the rod take a fair bearing on the bottom of the hole or on the cotter. The cotters also must be tapered to bear all over at top and bottom, and the conical bushes be turned a good fit, made of steel and split in halves.

The cylinders generally wear well, being vertical and usually provided with long pistons giving a large wearing and

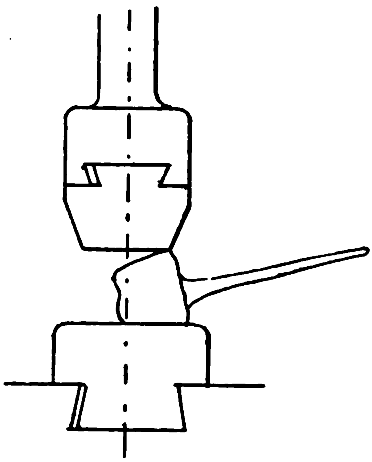


FIG. 321.

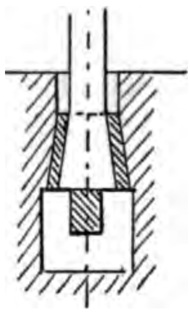


FIG. 322.

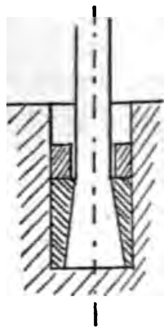


FIG. 323.

guiding surface. The treatment of these and the steam part generally is referred to under Steam Engines, Chapter IV.

Anvils and anvil blocks are always, except in very small hammers, borne on an independent foundation; great expense is often incurred in the preparation of these. The main principle involved is that the anvil shall rest on a mass of solid matter bearing a certain proportion to the weight of blow the hammer can strike, and if possible entirely separated from the foundations of the hammer itself, the object being to cut off the blow from the machine itself. This result is

rarely attained, the nearest approach to it is where a very heavy mass of iron forms the bed of the anvil block (Fig. 324), resting on wood piles. It is essential that the block shall be of a material capable of little elasticity, so as to oppose dead inertia to the blow. Nothing at present tried answers better than cast iron. Masonry and concrete are not hard enough and too bulky for their weight.

Anvil faces wear rapidly and often unequally, usually becoming hollow or concave and out of parallel. This should be remedied frequently by planing. The anvil blocks also

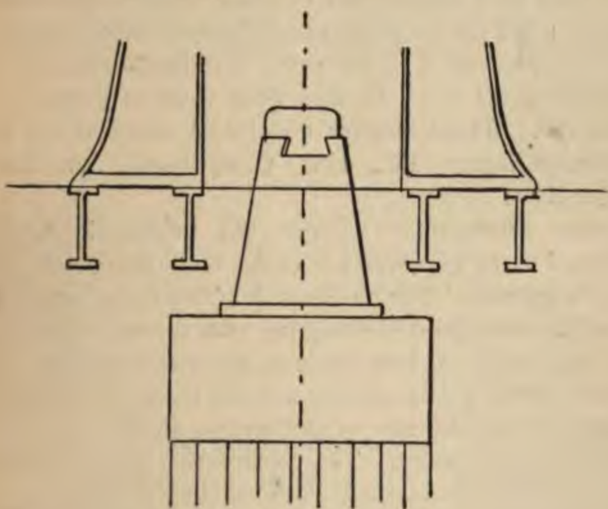


FIG. 324.

sometimes settle out of level, necessitating packing up. This last is best altered by adjusting the loose anvil face by tapered packings, but all such fragmentary bearings interfere a good deal with the solidity of the blow. There should be no springiness about a steam hammer.

Anvil blocks are of wrought iron, faced with hard steel. Some of the more modern ones are of cast crucible steel, and these are certainly cheaper than the forged ones, as a pattern can be made and one or two steel castings kept in stock.

A perfectly free exhaust is absolutely necessary, and for this reason the pipes should be larger than for a steam engine of the same diameter of cylinder. A very slight back pressure greatly diminishes the force of the blow.

Atmospheric or pneumatic hammers are not much used; in them air pressure takes the place of steam, and the compressed air is either maintained by an air pump or by a machine driven by shafting, pumping into a receiver; or is conveyed from some existing source by a pipe. There is no heat and therefore less wear and tear, in the cylinder and valves than with steam, and in other respects they are quite as handy; but the air pump usually gives trouble at the valves, and, involving as it does extra constantly-running parts, necessarily gives more trouble from wear of joints, brasses, guides, &c. These require no special mention, see Steam Engines, Chapter IV., and Compressed Air Engines, Chapter XIV.

Power Hammers.—Besides the pneumatic type just mentioned there are several varieties of power hammers (see p. 239, 'Engineers' Sketch Book'). The drop hammer is a rod and hammer head working up and down in guides, and lifted by a pair of grip pulleys above, which are brought together and grip the rod by a hand lever, and are released automatically at the top of the stroke, so that the rod and hammer fall by gravity. The construction is very simple and much used for light forging. The rapidity of blows is not so great as in either the steam, atmospheric, or the other types of power hammers described below, but the simplicity and handiness of the machine are a great recommendation. There is nothing likely to get out of order about it, and the wear is very small.

There are also several forms of power hammers which are driven by a crank and connecting rod, with a spring intervening between the hammer and the crosshead. Compound plates or laminated springs are generally used, and most of them have no means of either varying the speed or length of stroke of the hammer. The springs sometimes break near the end joints, which involves a new middle plate with forged eyes

at each end. The rest of the machine is liable to ordinary wear and tear of brasses, guides and anvil faces, which call for no special mention.

The old tilt hammer and forge helve are still at work in a few places where water power is available, and, cumbrous as they are, are capable of a deal of work of a rough kind, but are quite unsuited to a modern engineering works.

Plate and bar bending machines are in general use in smiths' shops, to bend flats, tees, angles and plates to some necessary curve. Plate rolls are arranged as Fig. 325, the two bottom rolls running in fixed bearings, and the upper one provided with rising and falling movement at each end, separately adjustable but coupled together also, so that the roll

FIG. 325.

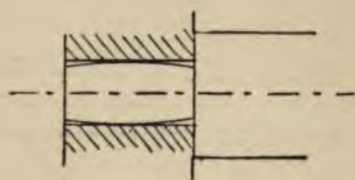


FIG. 326.

can be raised or lowered parallel or one end can be moved without the other to form conical sheets. The bearings of the top roll must be rounded or spindle shaped (as Fig. 326) to allow of these movements, and the driving gear at each end arranged to rise and fall with the roll, or long teeth made to the pair of gear wheels which drive it. The faults commonly experienced with these machines are: (1) springing of one or more of the rolls—causing unequal bending of the plates; and (2) most of them are not handy enough in the means for taking off a plate bent to a complete circle, as for boiler shells and tubes of small diameter, funnel and flue tubes. The best machines we have seen for these latter uses have an overhung bearing for the top roll (as Fig. 327), so that the opposite end bearing can be drawn off entirely, leaving the roll supported

by the two further bearings. Two or three speeds should be provided to suit plates of different thicknesses, and they should invariably be driven by belts, as the plates often jam and stop the machine, which, if driven by gearing, would cause a breakage.

Rollers for bending bars of various sections are similarly arranged and driven, but the rollers are very short, and the two lower rollers are provided with grooves of various widths and depths to take the flanges of T or L bars of different sections and widths.

The end standards of all these machines must be of great strength. The rollers, unless of large diameter, should be of wrought iron and turned very slightly larger in diameter in the centre than at the ends. If cast iron is used, the shafts should be of large diameter, and go entirely through the roll.

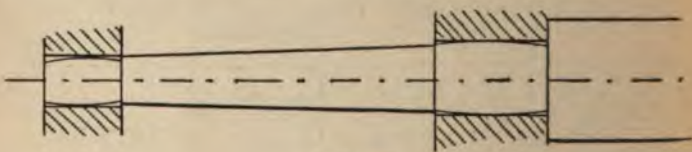


FIG. 327.

Fans, Blowers and Bellows, see Chapter XIII.

Punching and Shearing Machines. These are very heavily built machines, and the strains to which they are subjected are sudden and severe. The rising and falling movement of the punches and shears is small, so that eccentrics or cams are commonly employed for the movement, and are best applied directly over the guide blocks in line with the punch or shear. They are generally triple-geared, and a fly-wheel is keyed on the first motion shaft to give momentum to the punch on its working stroke; but as the fly-wheel acts through two pairs of spur gear there is some risk of breaking the wheel teeth. It certainly ought to be (theoretically) on the cam shaft, but its weight would require to be greatly augmented then to be of service.

For this reason hydraulic punching machines are to be preferred, they are much simpler, steadier and more reliable.

The construction and workmanship of these machines is rough, and the fitting inaccurate as a rule. The guides for the punch and shear blocks are seldom long enough to give them that amount of steadiness that is desirable, so that the punches wander about, and the shears often gape and require three times the power to cut that would be necessary with efficient guides.

Punches should be turned and the dies bored, as Fig. 328; this form is found in practice to give the best results. The punch has a little draft or taper on it, the end being dished, bearing a centre "tit" as shown. The die is slightly bevelled on its upper side, and the hole bored one-tenth the diameter

Fig. 328.

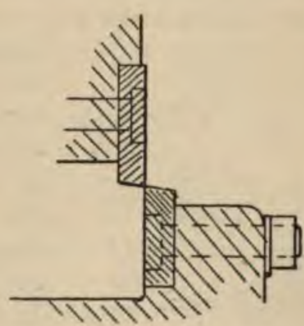


Fig. 329.

of the punch larger than the punch end, and tapered or relieved as shown. It is practically impossible to punch a hole in a plate smaller in diameter than the thickness of the plate.

Shears get very bad treatment in cutting off all sorts of bars; the strain on the shears being not central, but one-sided (see Fig. 329), tends to force the blades apart, and any slackness or bad fitting of the guides greatly augments this fault. The shear blades should approach at their cutting edges within $\frac{1}{32}$ of an inch, and be bevelled at an angle of 1 in 3 on the meeting edges. The steel must be exceptionally good tool steel, not too fine in the grain, and tempered as for cold chisels on the cutting edges. For punches the temper should not extend more than half an inch from the point.

Cold saw machines are a variety of milling machines carrying a circular saw or mill of a diameter sufficient to cut through the largest bar for which the machine has capacity. The velocity of the periphery of the saw is the same as that of a lathe turning the same diameter in the same metal. For simplicity most of them drive the saw spindle by a worm and wheel, but there is so much friction and end strain on the worm shaft, and consequent wear, that double or treble spur gear would be greatly to the advantage of the user. The bar to be cut is held in a vice or by cramps, and advanced to the saw by a self-acting motion attached to either the bed or the saw frame.

The saws must be of a thickness regulated by their diameter—a 6-inch saw will stand very well $\frac{3}{16}$ inch thick, a 12-inch, $\frac{5}{16}$ inch thick—and they must be considerably dished on both faces to relieve the cutting edge. The direction of revolution of the saw should always be as Fig. 330, not the reverse way, as they are liable to "grab" through the backlash of the feed motion. In cutting wrought-iron or steel bars or plates, either soapwater or oil should be dropped on the cut from a feed can. The running gear and working parts of these machines are simple and give no special trouble, but the saw spindle must not be allowed to become slack.

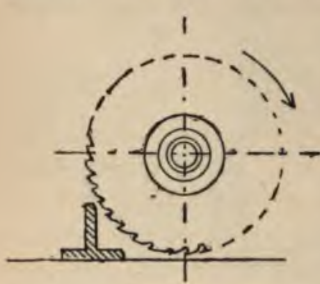


FIG. 330.

The general tools of a smithy, in addition to the machinery, comprise forges, anvils, hammers, top and bottom swages, tongs, chisels, punches, drifts, &c. The repair of these is a matter of every day attention on the part of the smiths themselves. In the forge the nozzle or tue iron is periodically burnt out and requires renewing. Some of them have a wrought-iron water tube through them connected to a circulating cistern, but these are often neglected, unless fitted with a constant supply ball tap, and if burnt out in consequence are expensive to renew. Many forges, however, have a simple

nozzle of hard white cast iron, and these are cheap and easy to renew. Anvils should be heavy; there is nothing saved by using a light one, quite the reverse. Tongs, chisels, drifts, swages, &c., are made, as a rule, as they are needed, but can be purchased also; the latter plan is the best and cheapest. It does not pay to employ men to make their own tools; the time so spent produces nothing for the profit and loss account, and they are seldom produced so cheaply at home as they can be purchased from the manufacturers who make a speciality of such tools.

CHAPTER XXXVI.

FOUNDRY TOOLS AND PLANT.

Cupolas and Wind Furnaces.—These vary in size and construction with the "make" or quantity of metal run, which also, of course, varies with the size of the moulding floor, the nature of the trade, whether light or heavy, and the class of castings produced. As a rule two cupolas are available, one for regular use, the other as a "stand by" for specially heavy jobs or in case of accident or repair to the other.

The old square stacks are quite out of date, and wrought-iron plate cylindrical casings universally used. The method of blowing also varies, and the pressure of blast from ½ lb. to 2 lbs. per square inch, the heaviest pressure being used for the highest furnaces. The wrought-iron casings will stand very well if the brick lining is not too tightly fitted; there should be a 1-inch space left all round, this is sometimes filled with sand. The firebrick lining should be constructed with segment bricks properly made for the sweep or circle, and jointed with fireclay. Every furnace scours more or less just above the tuyeres, and must be stopped every day or two for repairing the lining, for which ganister and fireclay are used.

Ladles and shanks should be of wrought-iron plate and well riveted; the smaller shanks are now made in one piece of steel, they are lined with ganister, which must be repaired or relined as often as necessary to prevent burning the ladle body, especially at the lips during pouring.

The core stove is a large brick vault closed by iron swing or sliding doors and having a coke stove in one corner and a flue out of the opposite corner low down. It is fitted with iron shelves, hooks and stands to hold cores of every form for drying. Most of these accessories are very primitive in form and might be greatly improved by a little study.

Repairs here are usually confined to the coke stove, which burns out any and every kind of bars and grates that can be contrived for it. Core wagons are made with horns and brackets to carry pipe and other cores, and run on rails in and out of the core stove. Dry sand moulds also require to be run in to dry. The quantity of fuel used is out of all proportion to the drying effected, and it is certain that some dry air method of desiccation would be much more economical.

Moulding Boxes.—Moulding, though a black and gritty business, is after all an art in which a wonderful amount of skill is often attained, but it does not seem to attract any but workmen of the lowest average intelligence. The boxes—or flasks as they used to be called—are generally in two parts, and occasionally in three or more parts for special castings; the deterioration and decay of these boxes arises almost entirely from corrosion caused by the wet sand, added to exposure to the weather; the iron flakes off in thick layers of oxide, and after a time the boxes become too thin to stand handling and break, after losing nearly half their weight of metal in corrosion. It would certainly pay every foundry to keep the boxes under cover and dry. There is no remedy for the corrosion caused by green sand moulding except to dry the boxes after use. Stacking them on the floor is not effectual, because all foundry floors are damp. Small boxes in constant use seldom last more than four or five years. In knocking out the sand, too, they are seldom

properly cleaned, the wet sand clings and keeps up the corrosive action.

Core bars are of cast or wrought-iron tube, drilled all over for air holes and fitted with end centres. Considering their cost the amount of care bestowed on their keeping is very small, in fact foundry plant throughout suffers severely from want of care and perhaps lack of arrangement; boxes, bars, rammers, gaggers, &c., are piled away as a rule in a most untidy way. There should be one man at least told off to see that every article has a place and is kept there, and this man would have no sinecure.

Brass Foundry.—This comprises one or more air furnaces, crucibles, tongs, boxes and benches. Air furnaces are giving way to blast furnaces, fitted with loose bottoms faced on the upper side with firebrick; there is a space of about six inches round the crucible, which stands on a firebrick in the centre. Coke is generally used, but gas carbon is much more lasting and cheaper. Such a furnace will melt 100 lbs. of brass twenty minutes after lighting up, and when done with, the bottom is dropped and the contents of the furnace dumped into the ashpit. The repairs are usually confined to the firebrick lining.

A good toplight and clean skylights are essential to moulding. It will pay also in winter to warm the shops; the damp sand sometimes freezes, and men cannot do effective work under conditions of bad light, cold and discomfort.

Foundry Cranes and Overhead Travellers (see Chapter XXIII.).—In the foundry a strong and very handy overhead traveller is essential; to be quick in picking up a ladle and carrying it to any given point is very important. The lifting and lowering gear should move without any jerking, especially in lifting boxes, as a jerk often destroys or ruins a mould. Steel wire ropes are therefore preferable to chains, and the winding barrel should be grooved spirally to ensure the rope or chain coiling correctly. Steam, compressed air and electricity are used for driving these overhead travellers, as also wire ropes. It is necessary that the driver be placed where he

can see and hear the whole of the work below him, and with his levers all arranged for easy handling.

A light crane worked by endless ropes, reached and handled from the floor, is also a very useful adjunct for lifting and handling boxes too heavy for two men and for turning over.

The cranes necessarily suffer from a constant fall of grit, smoke and dust, from which they cannot be effectually protected. Cleaning is therefore the only remedy.

CHAPTER XXXVII.

BOILER WORKS, TOOLS AND PLANT.

Boiler works employ punching and shearing machines and plate bending rolls (see last Chapter), drilling machines, flange and shell turning lathes, plate edge planing machines, hydraulic flanging presses and riveting machines, besides various heating furnaces, forges, bending and straightening blocks and plates, and small tools.

Drilling in boiler work is done partly in the plates, separately, and partly *in situ*, that is, in the structure of the boiler or other piece of plate work, so that the holes may exactly correspond; specially designed machines with radial arms are constructed for this work, and in some cases either Stow's flexible shaft drill or the ordinary ratchet brace have to be resorted to. Such machines must be very handy and capable of a considerable range to be of much service. We shall refer more in detail to these in connection with machine shop tools (Chapter XXXVIII.).

Flange and shell turning lathes are rough heavy tools of the break lathe pattern, fitted with a large face plate, treble geared for turning large diameters. They are used to face flange or L iron joints, to face the ends of shell rings, the edges of dished front plates, flue ring seams, &c., for the best class of work (see Lathes, next Chapter, p. 370).

Plate edge planing machines are employed chiefly for girder work ; the plates are laid one on the other to as much as six or ten inches in thickness, then clamped down by a row of screws in a heavy beam above them ; the edges are then planed either by a plain V tool, carried in a sliding tool box, or by a revolving mill, carried on a saddle running along a long planed bed and traversed by a long leading screw. With the V tool an arrangement is often used to make it cut also on the back journey ; the milling cutter usually takes off all the cut at one traverse. Great accuracy is not demanded and the machine is rough and heavy ; strength and speed of cut are more necessary than accuracy and finish. Its durability depends chiefly on keeping it clean and well lubricated. Such machines suffer a great deal from neglect, and often are allowed to become half choked with borings, scale and dirt.

Hydraulic flanging presses are heavily constructed with large rams, strong columns and arrangements for receiving various forms of dies and blocks on the platen, for flanging and dishing plates hot from an air furnace close by. There is nothing to remark in the construction of these presses, the leather collars, starting valves, pipes and connections are of the ordinary patterns, for heavy pressures up to three tons per square inch. Sometimes they are worked from an accumulator, which is the quickest method, but as this is a costly erection, a set of pumps is more generally used with two sizes of rams, a large one to run the press up as far as the pressure will permit, and a small one to put on the heavy final pressure. The only care required with these presses is to lubricate the rams and guides and to provide against freezing in winter, or a serious burst may result. The pumps and valves have been referred to, p. 105.

Riveting Machines.—The hydraulic method has largely superseded the steam and hand riveting methods, and a modern riveting plant is one of the few things a boiler works may be pardonably proud of, for the handiness and ease with which they perform their work, without noise or fuss, is in remarkable contrast to all the other operations of the yard.

Such a plant comprises a set of hydraulic pumps, an accumulator, pressure pipes and valves with flexible connecting pipes and a hydraulic riveter. The pumps and accumulator are usually fixed in some convenient place out of the way, but there are also portable accumulators and pumps which can be moved about the yard on a truck or wagon. These are such as have been described on pp. 105 and 310.

The riveting machine is suspended from an overhead traveller or swing crane with horizontal rail bar and travelling chain blocks, so that it can be easily and quickly moved in any direction around its work. The pipes conveying the pressure water are made with swivel joints or a flexible coil to admit of moving the machine about; the pressure used is generally 1500 lbs. per square inch. Pumping direct into the riveter is not quick enough for riveting, so that the accumulator is necessary to give a rapid thrust to the rivet die. The failures incident to such machinery are not frequent, they are generally confined to leakages, burst joints and pipes, worn-out cup leathers and worn starting and stop valves. For notes on these see p. 310. Of course the freezing of pipes, &c., must be prevented; otherwise beyond occasional lubrication and keeping clean very little care is necessary.

Steam riveters are nearly similar in construction and handling. The accumulator in this case is the boiler, the cylinder is very large in diameter because of the difference of pressure, 50–1500 lbs., but the closing of the rivet is more rapid; the quality of the work done differs little from hydraulic riveting, but what little preference is given belongs to the latter method. Compressed air is also used for riveters, the steam machine being suitable for either steam or air pressure. The supply pipes give less trouble by leakages and bursting in the steam method owing to the reduced pressure, but they require to be coated and to be so arranged as to need no handling, besides which trouble is experienced with the condensed water, and there is considerable loss of steam in this way. The steam cylinder and valve gear are subject to similar conditions as in a steam engine, except that they are worked for only a fraction of the time that the latter are

worked, hence there is but little wear, comparatively, but when needed the repairs are effected in the same way.

Other tools in use comprise portable punches (screw and hydraulic), smith's tools, rammers, drifts, hand-riveting tools, rivet forges, straightening and bending blocks of all kinds, and furnaces for heating plates and bars. Most of these tools are made on the works or purchased from a maker of such as specialities. They wear out or become broken and need constantly to be replaced. It does not pay to let workmen use indifferent tools, and careful attention to their efficiency is well repaid in the work done.

CHAPTER XXXVIII.

MACHINE SHOP TOOLS.

GENERALLY speaking the quality of workmanship and finish of these tools is greatly superior, with few exceptions, to those used in other departments of an engineer's works. This is due to the fact that great accuracy is required in the work done by them, and the workmen are more highly trained and more intelligent. It follows, therefore, as a general corollary, that such tools also need more care to maintain their efficiency. Good machine work cannot be turned out by poor tools—though it is remarkable what excellent results are sometimes produced by a clever workman with an antiquated machine—still we are justified in our belief that the best tools are the cheapest, and that it pays a master to keep his plant in thoroughly efficient condition. The difference between a workman and a duffer is seen at once in the condition of his machine and the state of repair of his tools. Apprentices often play such sad havoc with tools that it is customary to start them on the worst and oldest machines in the shop; only putting them forward as they show evidence of increasing care and ability. This saves the tools, but, we fear, debases the apprentice. We rather incline to the plan of putting a

lad or a man in a position of responsibility, and if he has anything in him it will come out; if not, he had better try some other line of life. From the point of view of the tools and their care and maintenance the fewer apprentices the better.

Lathes are the most important and most numerous class of machine tools. In this class we may include boring and cutting off machines, plain turning, screw cutting and surfacing lathes, gap and slide lathes, break lathes, wheel and axle turning lathes, and heavy face lathes, besides which there are numerous smaller varieties, as capstan head lathes, copying lathes, wood and pattern lathes, also special lathes for bobbin making and repetition work of all kinds.

It will be convenient to deal with these in detail first, and afterwards refer to special features for special work.

A lathe consists of a foundation, a long bed plate—mounted on legs to a convenient height for the workman—a running spindle and fixed bearings or "fast headstock," a traversing spindle or loose headstock, a tool rest or holder, a countershaft for driving, with belt and such other accessories as are requisite for special turning, such as chucks to hold the work, slide rest, screw cutting and surfacing gear, capstan, tool rest, &c.

A lathe should stand on a rigid foundation, and be perfectly level on its bed; it need not, as a rule, be fastened down by bolts, as it is usually heavy enough to stick to the floor. In the case of a long bed—sometimes jointed in two or more places, and with three or more legs—the setting requires great care. Vibration of the machine is incompatible with accurate turning.

The bed, assuming it to be true when new, is liable to wear where the saddle or rest is most used, that is, near the fast headstock. An old lathe bed which has got so worn must be replaned and scraped, and the saddle gibs refitted to it. A good deal of this wear is caused by the dust and borings getting under the saddle, and also by corrosion from using water on the tool in turning wrought iron or steel. Every machine ought to be cleaned up *before leaving work at night;* if left till morning—as is too frequently done—corrosion is greatly

increased. A lathe bed may have been set "winding," that is, higher at opposite corners diagonally than at the other two corners. This can be tested by sighting along two straight-edges laid on edge across the bed, or by a spirit level and straight-edge used diagonally along the bed. A lathe bed cannot be too heavy, but very often is too light, and springs when the centres are screwed up, and also when a cut is on, as shown in exaggerated form in Figs. 331 and 332. This want of stiffness causes the tool to "chatter," that is, vibrate, making a notched or serrated cut instead of a smooth one. Other defects produce the same result also, as the looseness of the saddle, slide rest or tool box, or the running spindle; these may, however, be set up, but a weak bed cannot be strengthened. In gap lathes this fault sometimes occurs when the gap is out and its stiffness removed from the bed. The best form of gap lathe bed is the box bed, in which the gap takes a bearing on the foundation.

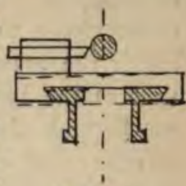


FIG. 331.

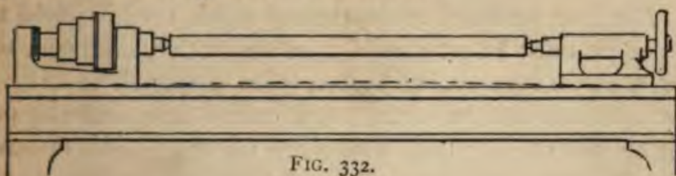


FIG. 332.

The fast headstock may be single or back geared, and consists of a main spindle and bearings carrying a speed pulley, and—in the case of back gear—a second spindle, with eccentric throwing out gear and two pairs of spur gear. For accuracy the main spindle should have its nose end and centre hole finished while running in its own bearings, though this is seldom done. The face plate and other chucks which are fitted to it should also be finally trued up on the main spindle. There are two kinds of bearings employed, conical and parallel, the latter have split brasses and caps, as ordinary pedestals, the former have conical bushes only; both methods have their advantages and advocates. The conical bearings require that the tail screw shall be kept close up to take the thrust of the

work or the cones may jam; with parallel necks this cannot occur, but the bearings sometimes wear sideways, so that they cannot be made to run without side play; they then require reboring, and the joint of the brasses to be planed so that they come closer together, and a parallel packing must be placed under the brasses to bring the lathe centre up to the level of that of the loose headstock. With conical necks this does not happen; but when worn so much that the collar of the spindle runs close to the bearing it becomes necessary to make new bushes after trueing up the necks in a lathe. These bushes are sometimes made of steel, but large ones are almost invariably of gun-metal or phosphor bronze; and large lathes rarely are fitted with conical necks at all.

In the best tools the back gear is cut in a wheel-cutting machine, in others it is cast from machine-cut patterns; there should be but little backlash, as the noise is very unpleasant, and the teeth show all round the finished turned work. The spindles need well oiling to run freely, and when in good order there should be very little friction.

The loose headstock seldom gives much trouble; like the fast one it must be set carefully in line with the lathe centre line, otherwise the sliding centre, when projected to different distances, will not be in the same centre line, and the work will be out of parallel. The screw for this spindle of course wears in time, and being enclosed often gets neglected as to oiling.

The lathe centres frequently require turning up; the running centre is usually not hardened, but the fast centre is hardened, and of course has to be turned in the running centre hole. There are slight differences of fit always, so that they may not be in exact line after being turned up. This can only be remedied by careful scraping with a V scraper inside the centre holes. Ordinarily, however, the turner finds, by revolving them in their holes, one position in which the centres come in line, and marks them so that they are always put in in that relative position; and in fact this precaution is necessary in any case to ensure accuracy. The centre lines of both headstocks can be set

parallel with the bed by squaring up from the centre line of the bed to each end of the spindles. A gauge can be made for this purpose which will serve to correct them at any time (Fig. 333). Slight differences in level merely are not of much consequence in the centres.

Chucks.—Besides a face plate or two and a catch plate, which are supplied with every lathe, one or two chucks are essential, and for wood work, brass turning, ivory and other light uses, many special chucks are required. For engineer's lathes, a large 3 or 4-jaw chuck, a small ditto, and a 2-jaw chuck for drills, mandrels and plain turning, without the back centre, are necessary for the usual round of work. These should be bored and screwed to the lathe running mandrel

FIG. 333.

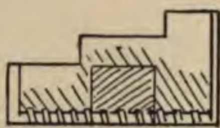


FIG. 334.

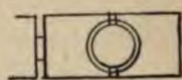


FIG. 335.

nose as accurately as possible, and, for first class work, trued up afterwards on their spindles. The wear of chucks is chiefly confined to the screws and nuts; the jaws gradually become slack, and having no means of taking up the wear, must either be worked in this condition or renewed. Slackness of jaws does not, however, necessarily cause errors, as in tightening up the jaw takes a bearing at both ends on the chuck body and thus becomes firm. The screws outlast the nuts. Refitting is rather a nice job, especially with the American half-nuts cut, as a rule, in the jaw itself. When the threads become worn out or stripped the best method of repairing, if the jaws are good, is to bore out a hole (as Fig. 334) as large as possible, and make half-nuts in pairs out of round steel turned to fit the holes (as Fig. 335), tap out or chase the hole in the bar and part in two; each half-nut can then be fitted in its jaw with a little care. These nuts can be hardened. In the ordinary jaw chucks the nuts are generally forged solid with the jaw, and if the threads strip a new jaw must be made,

or else the hole tapped out larger, and larger new screws fitted; bushing is usually out of the question.

Two-jaw chucks generally have a right and left-hand screw at the side of the jaws, gearing with segment threads cut in the jaws. These chucks do not last long, because the jaws are insufficiently guided, being usually as deep as the length of guide. They often grip an article at the front end only, and the cross strains thus produced soon loosen the jaws, resulting in rapid wear of the segment threads. In some cases these can be renewed in the same way as Fig. 336, by drilling a hole through the jaw and fitting the half-nut in it.

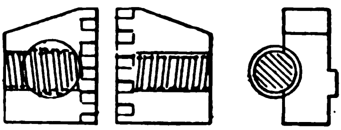


FIG. 336.

In wood and other light turning the chucks used are generally home made; that is, bored, fitted and turned up on their own spindles, see Chapter XLI.

In repairing Combination and Universal chucks which are fitted with bevel pinions and circular racks, these parts are best obtained from the makers; the pinions are solid with the screws, and usually wear out first. A good wheel-cutter can, however, cut them out satisfactorily, and new racks can be made in malleable cast iron, but allowance must be made for shrinkage, which generally involves a pattern. It is, as a rule, the most satisfactory to forge a wrought-iron ring, turn it up, and have the teeth cut by a wheel-cutter.

Oval, eccentric and other special chucks are so little used that we need not refer to them.

The Saddle, Slide and other Tool Rests are constructed to slide on the bed, and to hold the various tools required. The most important feature in all these is their rigidity or firmness under the cut, which, in the case of the slide rest, must not be lessened by its free movement. Plain T rests for hand tools are simply fixed in a bored socket by a set screw. Compound slide rests, however, have at least three movements, as a rule, longitudinal, transverse and revolving. Good fitting is therefore essential to prevent shake and springing, the gibbing of the slides must be carefully done and every face scraped to a

good fit. The height from the bed to the lathe centre often precludes a sufficient section of metal in the slides, &c., to ensure ample stiffness. Increased width of slides, therefore, is the only alternative. Many lathes are very deficient in stiffness in the tool post, and cannot possibly turn out good work. The saddle should be heavy and broad, and well fitted to the bed vees. Borings, dirt and water should always be quickly cleaned off the bed and saddle, as they mix with the oil and form a gritty paste, which scratches the surfaces and necessitates easing the slides to the point of looseness. One important improvement not yet effected in the lathe is a means of protecting the whole of the saddle from this constant source of trouble.

Injuries and deterioration to which these parts of a lathe are liable, include wearing of all the guide surfaces, worn screws, worn nuts, looseness and irregular wear of the saddle vees, worn out leading screw nut, broken or stripped tool box studs. These repairs involve no particular difficulties, but must be carefully done, especially the renewing of the slide faces and vees, which can usually be done by the scraper, file and surface plate unless too far gone, when they must be planed first. The object to be aimed at is to ensure the vees fitting well at the ends, for which reason they should be left rather concave than convex, wear and tear tend to make them convex.

Sliding and surfacing motions are always driven from the back shaft by worm and wheel gear driving—for the sliding motion—or the rack and pinion hand traversing motion in front, and for the surfacing motion, by spur gear direct to the transverse saddle screw. The pinion and rack motion often gives trouble, chiefly because it is bracketed down so far below the saddle that it does not drive directly enough in line with the saddle itself, and is too much overhung downwards in fact. Some American lathes have the rack inside, or on top of the bed, which, if it can be kept clear of chips, is much better for driving ; the pinion and the rack frequently become injured from springing, and the pinion shaft bent from the resistance of the saddle. The back shaft gear seldom gives

much trouble, it suffers rather from neglect, being a good deal out of sight, but its motion practically keeps it clean, if oiled.

Screw-cutting gear comprises leading screw and clamping nut, change wheels, reversing pinion and segment, and idle wheel centre and bracket. The best form of thread for the leading screw is certainly the truncated V (Fig. 337), as it allows the clamping nut to go on and off more readily and takes up a good deal of the wear of the nut which, as it wears, settles deeper into the screw thread. The hand lever of the clamping nut should always be balanced, so that when loose it cannot fall and throw the nut in gear when not wanted. Many old lathes are lame from this accident. Change wheels get broken teeth, chiefly from being set too deep in gear. The only certain remedy for this is to half shroud them all and turn the edge of the shroud to the pitch line. They are invariably cast from machine-cut patterns.

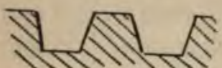


FIG. 337.

Cleaning and oiling are very important items in the care of lathes—they are at times half buried in borings and dirt, and therefore need the more attention between jobs.

Planing machines are of all sizes, from the little hand planer to those with beds 40 or 50 feet long. Usually the bed and work traverse and the tool is stationary, but with some wall planers and others the bed is fixed and the tool travels. The fixed bed is box shaped, with V grooved planed top slides, and the travelling bed has corresponding planed vees projecting from its under surface and sliding in the V grooves of the box bed. The capacity is usually stated as the greatest dimensions in width, height and length, the machine will operate upon. The travelling bed is usually some feet longer than the length of cut, and the cross dimensions depend upon the inside width and height of the standards and cross slide. The stiffness of the machine depends on the weight and strength of the travelling bed, and the design and consequent stiffness of the standards. The bed is moved by rack and pinion beneath it, and if these are not well geared with machine cut teeth every tooth can sometimes be seen

on the finished work; the best machines have a large intermediate wheel between the pinion and rack, which gears better with the latter without the same tendency to lift the bed. The tool slides, vertical and horizontal, are plain double guides with V edges, and usually two tool boxes are provided, the machine taking two cuts at once and having a quick return motion. This is more manageable and more generally useful than a turn-over tool box to cut both ways, as it is difficult to get the tools adjusted to cut evenly. A planing machine takes a great deal of power to drive it, as there is much friction on the guides, which need plenty of oil.

The quick return driving gear is generally noisy and often troublesome. It wears out a good many belts from the continual shifting, and is certainly more tolerated than approved of. The length of cut or travel of the bed is regulated by an adjustable stop on the bed which strikes a lever and reverses the belt, the same motion operating also the tool feed gear.

It is essential that the machine has a rigid foundation and that the table is level and out of winding.

Wall planers frequently have a moving tool box and a plane bed on which the work is fixed, the cut being generally vertical, and there is no doubt that this method will eventually supersede the other; the machine will then take up much less space and consume much less power than now, besides which it is obviously more scientific, in the case of heavy work, to move the tool over it instead of moving it under the tool. Planing work costs, as a rule, twice as much as turning, for equal surfaces, because in the latter case the tool is always cutting and at greater speed of cut than the planer. When we come to small surfaces, shaping, either by hand or power, becomes much cheaper and quicker.

The wear of planing machines is chiefly found on the main slides and the travelling gear. The tool slides, screws, &c., do not wear much, as their motion is slow and intermittent. As in the lathe bed, the planer bed wears hollow and requires truing up; in time the guides get cut and grooved also. The driving gear wears very fast; the constant reversing injures it and soon makes it loose and noisy. Plenty of

oil is needed. The machine does not, however, suffer as the lathe from being strewed with borings and grit, the table covers most of the working parts and protects them.

Shaping machines are very useful for small surfaces. A sliding reciprocating arm carries a tool box and has a traverse motion with self-acting feed. The work table is a bracket or cantilever plate with rising, falling and traversing motions by screws.

The tool arm or ram is heavy and runs in a V groove in a saddle similar to a lathe saddle, and having a similar traverse screw motion. A fault in design is that the tool arm is not balanced, so that when at its greatest projection its weight causes it to bind in the guides and thus become hard to move. It wears also most at the part most used, that is, on short strokes, and this when altered to long strokes becomes stiff and cannot be so well gibbed up. The same wear takes place in the bed at the part where the saddle is most used, but not to the same extent as the tool arm.

The table of the machine should be occasionally re-surfaced by its own tool for accuracy. The driving motion is by back shaft carrying a travelling spur pinion, gearing with a spur wheel having a variable throw crank pin which travels in a slot in a vertical lever, the upper end of which is connected by a connecting rod to the tool arm. A considerable amount of wear falls on this slotted lever and on the crank pin and block which slide in the slotted lever and spur wheel. This drives the cut on the "outboard" or over top stroke, returning the tool quickly on the under or back stroke. This wear does not injuriously affect the work, but causes noise and jar at the ends of the stroke. The feed gear, which drives through an idle wheel to the nut of the traverse screw, sustains a good deal of wear, the nut and screw also; the latter, like the bed, wears most in the part most in use for short strokes. The feed gear occasionally gets broken through the machine running on to the end of the bed in the absence of the machinist. For repairing such wheel teeth, see p. 253.

The cantilever tables of such machines are seldom stiff

enough, because sufficient vertical distance is not allowed between the bolts which secure it to the apron slide; a table projecting 20 inches will be found to have perhaps only 6 inches or 7 inches between these bolts. This is an oversight, and such a machine, though amply rigid elsewhere, may spring a good deal at the table, see Fig. 338.

Hand shapers are not so much used as they deserve to be. For small surfaces up to 6 inches long they can do twice or three times as much work as a power shaper. Those with a simple hand lever are preferable to those having revolving crank motion. The length and speed of stroke are directly in control of the hand. They should, however, have a self-acting feed to obtain an even surface on the work. Similar attachments are sometimes applied to a lathe bed for small shops or for amateurs.

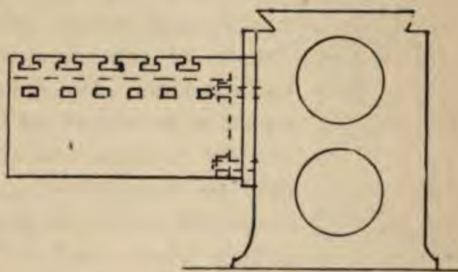


FIG. 338.

Drilling and Boring Machines.—The structure of these is very varied; although the actual work done is simply to revolve a drill and feed it down to its work at an even speed, the machines that perform this operation are as multifarious as the varieties of lathes, and are employed on a very extensive range of work. There are first, hand machines to fix to a bench or a vice, small power drills, large pillar drills, with many speeds and back gear, rising and swinging or compound tables. Then we have wall drills with the same range of movements, and radial arm machines, either fixed to a wall or a bed plate. There are also multiple drills for boiler and plate work, girders, &c., and special machines for key grooving, vertical boring of cylinders, &c.

In all these machines the essential feature is a vertical spindle driven at one of many speeds, and raised and lowered by a screw motion to which hand power or a self-acting feed

may be applied. The difficulty with them all is to maintain the running spindle free from play or chattering in its bearings, and the avoidance of backlash in the vertical motion. The latter is particularly objectionable as it allows a drill to "grab" or drop and dig into the metal on going through the bottom of a hole, and for twist drills this is often fatal. Small machines, in which the feed screw bears on the top of the running spindle, are very liable to this fault through the wear of the connecting parts. We have remedied them in the way shown in Fig. 339, where the backlash can be taken up by the screw collar.

Larger machines have the feed screw around the drill spindle as a sleeve, with adjusting lock nut at top. These will take up the wear between the spindle and screw, leaving only the backlash caused by the screw wearing in its nut bush to deal with. The spindle bearings are usually coned so as to take up the wear of the spindle, but not always, and any slackness causes the drill to wander and cut irregular holes. No very great stiffness is required in these machines except when used at slow speed for boring cylinders, &c., vertically, and hence we find the frames as a rule light. Multiple machines are of the same construction, with several spindles, the bearings of which can be separated from each other to any required pitch of holes. The wear of these machines is chiefly in the spindles and bearings—the spindles wear hollow and the bearings sometimes oval. The feed gear, screw and nut, especially in small machines, wear badly but involve no particular skill in repairing.

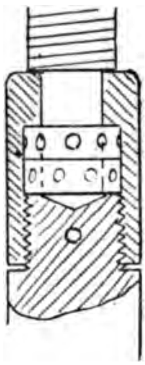


FIG. 339.

Radial arm machines are becoming a favourite pattern, as they will cover a considerable area and the work is able to be fixed on a solid bed instead of a light movable one, as in the other patterns. They are more complicated, however, and in some of them the arm springs upwards against the pressure of the drill feed, tending to "grabbing" as the drill goes through the bottom of the hole. In others the provision for

securing the arm from radial springing is insufficient, causing the arm to play a little from side to side as the drill revolves. Such machines cannot produce good work.

For many light purposes a machine with hand lever feed is best, as a man can feel the resistance of the drill and apply the proper pressure very efficiently. In fact, for small holes and twist drills it is almost a necessity. With such a lever feed we have cut as many as 1500 holes $\frac{1}{8}$ inch diam. through $\frac{1}{2}$ inch of wrought iron, by twist drills, without a breakage.

Slotting Machines or Vertical Shapers.—These have a vertical tool arm or slide driven by a similar gear to the shaper, but there is no side traverse of the tool arm, the work being moved by fixing to a compound table, provided with two cross traverses and a circular motion also.

FIG. 340.

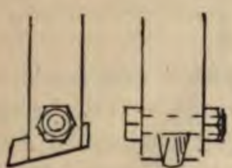


FIG. 341.

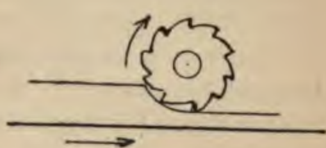


FIG. 342.

The faults found in these machines are: springing of the tool away from its cut, slackness and jumping from wear of the driving motion and guides, backlash of the screws and guide of the compound table, allowing the work to spring away from or grab into the cut.

The tool slide should always be balanced. Many machines are without this and run unsteadily in consequence. The springing of the tool is, no doubt, partly due to its length, overhanging the tool-box, and the fact that, unlike all other machine cutters, it cuts end on, and therefore has only its own stiffness to resist springing, whereas other tools, though they undoubtedly spring also, do not spring away from their cut. This seems to indicate that a stiff tool holder and small cutter, as Fig. 341, would be a better tool to use instead of

the ordinary tool, Fig. 340. The slotting machine is one of the least used machines in a works as a rule, and therefore seldom gives much trouble from wear and tear, but we have not seen a machine yet free from the fault of springing to a marked degree.

Milling machines are coming very much to the front now, and perform a great variety of uses impossible to other machines. They are used to execute work also formerly done by the shaper and planing machine. The machine has a running spindle and headstock almost precisely similar to a lathe, and with back gear also in the larger sizes for greater variety of speeds, which vary with the diameter of the milling cutters and the nature of the material operated on.

SPEEDS AND FEEDS OF MILLING CUTTERS. (G. Addie.)

For steel	36 ft. per minute.	Feed ..	$\frac{1}{2}$ in. per minute.
,, wrought iron ..	48 ,, ,,	Feed ..	1 ,, ,,
,, cast iron	60 ,, ,,	Feed ..	$1\frac{2}{3}$,, ,,
,, brass	120 ,, ,,	Feed ..	$2\frac{2}{3}$,, ,,

The work is fixed to a compound slide table having two horizontal movements or traverses, and rising and falling motion also. For regular cutting, and indeed for the safety of the cutters, a self-acting feed is essential. The headstock, spindle, bearings, &c., are subject to precisely the same conditions as a lathe headstock, except that slight inaccuracies of true centre or of line are of no consequence, but the work table should be correctly square every way with the spindle.

The faults experienced with these machines are springing of the work through weakness or looseness of the table, or of the headstock; backlash of the traversing screws, allowing the work to overrun the cutter and cause a "grab"; looseness of the table slides may cause the same fault. As a rule the cutter should revolve so as to prevent this "grabbing" (Fig. 342), but there are those who advocate the reverse method, because by it the cutters get a better hold of the metal by taking their full cut on entering than by gradually increasing their cut, as they do when run as Fig. 342, but practice shows that this can only be done with a machine in good order and free from play and backlash.

A difficulty generally occurs in vertical cuts by lowering the work table. It is so far overhung that the vertical slide must be very loose to allow it to descend at all, and jumping follows. A good stiff machine will take an inch cut four or five inches wide with ease, and finishes its work at one cut. In America they are much more generally employed than in England, and for heavier work. The gibbing of the work table slides, and the wear and backlash of screws and nuts are the chief repairs needed. The table requires replaning at intervals and the headstock lining up to the table.

Screwing machines are in reality a variety of lathes with hollow mandrels, but provided with reversing motion and a sliding grip or holder for the bars to be screwed, the dies being fixed to the face plate on the running mandrel. The machines are backgeared for heavy screwing and seldom cut threads larger than 1½-inch Whitworth or 2-inch gas: it is found that larger sizes are better cut in the lathe. The reversing gear wears badly as a rule, and becomes noisy and shaky. All machines having reversing motion have the fault of noisiness and looseness, not found to anything like the same extent in machines that always run in one direction. The die box or chuck encounters a great deal of strain and hard wear, resulting in loose dies, which dig into and tear the work, producing badly formed threads. The work-holder or travelling grip is seldom stiff enough or sufficiently well guided to remain in good order, and both these defects are intensified by the inaccurate centering of the dies, which soon begin to wobble out of truth. The work also is often rough bars, not properly straightened, so that correct centering is impossible. The grip or holder is also a very rough form of double V grip, and seldom accurate or free from a great deal of play: this arises partly from the fact that it is made short enough to hold bolts by the neck, allowing the dies to cut up to within about one inch of the head, so that only a short grip is possible.

The wear of headstock bearings is not of much moment; the dies, of course, need recutting and relieving at intervals, and they should be always adjusted centrally, as wobbling

destroys the running of all the other parts of the machine and causes looseness all through. Plenty of oil is needed, and a deep pan or receptacle is provided in the bed of the machine to receive it.

Accuracy is certainly not the distinguishing feature of the screwing machine as now constructed. It operates chiefly on rough material such as black bolts. Finished threads are generally made in the lathe, and in special forms of it provided with capstan tool rests for the several consecutive operations required in turning and finishing a screw.

In many American machines the dies are stationary and the bolts are revolved. This plan is very well for small work, but becomes bad for long heavy bolts and tubes. In these machines the dies are fixed in a circle in a revolving head which can be turned round to bring any size of die opposite the work. All screwing machine dies cut a full thread at one operation, and therefore are bell-mouthed and "backed off" or relieved considerably between the flutes. The fitting and steadiness of the sections of the dies is of the greatest importance, a very little play will make them cut badly. The length of thread in a die is seldom more than two-thirds the diameter of the bolt, and a thread has to be cut to the full depth in that length, whereas in tapping holes the taper tap is about six times as long as the diameter of the bolt to do the same work, and is then followed usually by two others to produce the full thread. This serves to show that a very heavy strain comes on the dies. They must be well fluted and the flutes cleaned out every cut, or the impacted borings will strip the thread. Some dies are but indifferently supplied with such clearances and give a deal of trouble from this cause. In screwing up long threads it is often necessary to stop and clear the dies once or twice, whereas they should deliver out their borings as they cut. The foundations or levelling of these machines are not of much consequence, having no appreciable effect on the machine or the work executed by it. Small hand machines are very useful for odd jobs, and are generally fixed to a bench or on a standard.

Emery and Stone Tool Grinders.—Formerly all tool

grinding was effected on a grindstone, and some engineers still prefer the grindstone for many purposes and still use it. It runs slowly in water and cuts slowly also; it wears down rapidly, however, and requires turning or trueing up frequently, in fact, this trueing up uses up more of the stone than the tool grinding as a rule. Whatever faults are found with emery wheels are due to their being generally used dry, and to using too fine, or in some other way an unsuitable grade of emery, or to running them too slowly; they should have a peripheral speed of 4000 feet per minute.

But for grinding quickly and with little wear of the stone the emery wheel is immeasurably superior to the stone, besides being a smaller affair altogether and not requiring water. Water can be used with it, but with ordinary care the tools need not become heated and may be dipped in a pan of water placed close by to keep them cool Add to this that the emery wheel will grind off hard knots, edgings and chilled skins of castings and such like work, and its superiority is placed beyond doubt. The best machines for running have two wheels, one at each end of the spindle. This gives greater steadiness at the high speed adopted than is the case with a single wheel. The bearings require to be well shielded, as the ground emery finds its way into them and rapidly cuts the journals. Long bearings are desirable and should be well oiled. Several special forms of the machines are made for saw gumming, gulleting, twist drill grinding and numerous other uses for which stones are quite unsuitable.

Grindstones are usually mounted on roller bearings and run in a water trough at a slow speed, about 600 feet per minute on the periphery. In a workshop where power exists they are of course driven by a belt, but are also frequently worked by hand or a foot treadle. The water and ground off dust soon destroy the bearings and spindle. For fine grinding, as for joiner's tools, they are preferable to the emery wheel, though the tools can be more quickly roughed up on the latter and then finished on the grindstone. Turning them up true at intervals is a very unpleasant process, usually done by

the flat end of a round iron bar which is revolved slowly to present fresh edges to the stone. The grit and dust fly all over the shop and get into the tools, and give rise to a good deal of energetic language at times. To avoid this the stone is sometimes fixed outside, but men do not like to go far away from their machines to grind a tool, and driving also becomes a matter of difficulty. Their slower speed undoubtedly prevents their being replaced by emery wheels more extensively. The most important matter in fixing a grindstone is its true running; any wobble soon gets augmented by using the stone. Soft places occur in them and rapidly cause a hollow or flat in the circumference which very quickly enlarges. A 10-inch emery wheel will as a rule outlast a 30-inch stone, and do three times as much tool grinding.

Speeds of Cutting Tools. Angles of Tools.—Wood, 30° to 40°; wrought-iron, 60°; cast-iron, 70°; brass, 80°. The angle of relief varies from 3° to 10°.

Speed of Drills.—The circumferential velocity of the drill should be about 100 feet per minute for cast iron, and 150 feet for wrought iron. The following table of revolutions for different sizes of drills for cast and wrought iron is calculated on this basis:—

Diameter of Drill.	Revolutions of Drill per minute.		Diameter of Drill.	Revolutions of Drill per minute.	
	Wrought Iron.	Cast Iron.		Wrought Iron.	Cast Iron.
¼	225	150	1	55	37
⅜	150	100	1⅛	50	33
½	112	75	1¼	45	30
⅝	90	60	1½	38	25
¾	75	50	1¾	30	21
⅞	64	43	2	28	19

Pressure on head of twist drill in pounds requisite to produce a proper cut equals diameter of drill in inches multiplied by 1500.

SPEEDS OF MACHINE TOOLS.

Work.	Speed, feet per minute.	Work.	Speed, feet per minute.
Shearing and punching	2	Turning wrought iron ..	25 to 40
Turning chilled rolls ..	3 to 4	Turning steel	20 to 25
Screw-cutting steel ..	7 to 8	Turning gun metal ..	20 to 40
Screw-cutting gun-metal	30	Turning soft brass ..	40 to 100
Boring cast-iron cylinder	10	Turning wood	1000 to 2000
Turning cast iron	15 to 20	Wood-moulding cutters	3000 to 5000

Miscellaneous tools employed in an engineer's machine shop include vices, surface plates and tables, gauges, ratchet braces, hammers, chisels, spanners, punches, reamers, stocks and dies, chain blocks and overhead travellers (see Chapter XXIII.), trolleys.

Vices are now generally made with parallel movements and quick opening and closing devices, some of which are very effective, and save much time. A good vice should be of wrought iron throughout, with steel renewable jaw faces and steel screws and nuts. The ordinary tail vice soon wears out its screws and nuts because the varying angle of the screw and nut is badly provided for, or not provided for at all. Somehow it happens that a vice rarely gets oiled, and the filings clog its screw and nut. The newer patterns of parallel vices have these parts enclosed, as a rule, and thus protected, which is an important improvement. False jaws or "clams" of sheet brass, copper, lead and wrought iron are used for holding finished work to prevent bruising by the teeth of the hardened jaws. A vice should not be fixed too high, as is often done, nor should they all be at one height, for fitters are not equally tall, and there is a height at which they can best use their file or chisel, and it is worth a little pains to ascertain it, and set the vice to suit. New screws and nuts for tail vices can be obtained at almost any engineer's stores. With patent vices it is best to obtain duplicate parts from the makers. Vice benches are seldom as firm as they should be; in fact an iron

bench will be found a great advantage, and it requires to be well secured to a wall or to the floor to resist the strain of bending bars, heavy screwing, &c., done in the vice.

Surface Plates and Tables.—A large planed table on legs, properly levelled and kept clean, is a very necessary adjunct to a machine shop for marking off work, &c. Two or more surface plates are usually kept, including one with handles for applying to any surface to be tested by hand. These plates are ribbed at back, cast face down in soft iron, planed and squared on the edges and scraped true to a standard plate, and should be very accurate, especially for use on gas engine slides, engine slide valves, hydraulic ditto, &c. They are best kept oiled and laid in a box on a layer or lining of baize, and should not be used for any rough work or surfaces not machined.

Gauges and Tool Room.—Most modern shops have a tool room, and in large works some special machine tools for re-cutting, renewing, repairing and making new tools and gauges, and in this room are kept and classified all the tools of precision or otherwise, required for every machine in the works. This is undoubtedly a valuable institution. Sets of gauges for each size of machine manufactured, cylindrical turning gauges, templets of all kinds are made and kept ready for service, and all tools for the machines are given out, and when returned put in good order for the next user. This plan tends greatly to preserve the tools, and needs further supplementing by the employment of one or more first-class men to keep in order the machine tools, which are now generally left to the care of the machinists (see also Chapters XLVII. and XLVIII.).

SECTION IX.—*WOOD MACHINERY.*

CHAPTER XXXIX.

SAWING MACHINES.

THIS section includes an extensive range of machines for operating on wood, from tree-felling to carving medallions and ornaments; we may divide it into reciprocating machines and rotary machines. The first class includes all saws (except circular ones) and mortising machines. The second class includes circular saws, band saws, moulding, tenoning, grooving, tongueing and planing machines, wood-turning lathes, panel planers, sweep moulding, boring, copying and carving machines, veneer machines, &c.

The aim of modern improvements in the sawing machines is to cut the wood accurately with very thin saws, to avoid the waste of valuable timber in sawdust, and very great progress in this way has been accomplished recently. Circular saws will never do this, however, because they will not stand in shape without sufficient thickness to prevent buckling. Band saws are becoming very generally used, as they cut continuously with a thin and narrow saw, and with a minimum of power expended. But for cutting up logs a set of reciprocating or frame saws is certainly the quickest and cheapest, as many cuts can be made at once going over. There are both vertical and horizontal machines made for this operation.

The distinguishing characteristic of wood machinery is its high speed and comparative lightness of construction. All the operations of hand tools have been adopted in wood machines except that of planing. Machine planes are all rotary.

SPEEDS AND FEEDS OF WOOD-WORKING MACHINE TOOLS.

Class of Machine.	Speed at Periphery or Cutting Edge.	Rate of Feed.
Circular saws	6000 to 7000 ft. per minute	15 to 60 ft. per minute
Band saws	3500 ft. ,,	25 ft. ,,
Gang saws 20-inch stroke	120 strokes ,,	$1\frac{1}{2}$ ft. ,,
Scroll saws	600 to 800 strokes ,,	
Planing machine cutters ..	4000 to 6000 ft. ,,	$\frac{1}{20}$ inch for each cutter
Moulding ,, ,,	3500 to 4000 ft. ,,	$\frac{1}{25}$,, ,,
Squaring up ,, ,,	7000 to 8000 ft. ,,	$\frac{1}{30}$,, ,,
Carving drills	5000 revolutions ,,	
Machine augers $1\frac{1}{2}$ in. diam.	900 ,, ,,	
,, ,, $\frac{5}{8}$ in. diam.	1200 ,, ,,	
Mortising machines	250 to 300 strokes ,,	

Circular saws are the commonest of wood machine tools, and vary in diameter from 6 inches to 6 feet. They take considerable power to drive them, however, and from their thickness cut a wide kerf, so that they are only used for cheap woods and for further cutting up planks and scantlings from the frame saws. The great power required is chiefly due to the friction of the surface of the saw in the cut and in the packing groove in the saw table. The saws must be perfectly circular, very slightly dished on both sides, and fixed on the spindle to run very true. Long bearings are advisable for the spindle. Sufficient space must be allowed between the saw and the table to allow sawdust and chips to fall through without getting jammed, and for this reason the table should be bevelled a little, as Fig. 343. The fence is set slightly out of parallel with the saw, to allow the kerf to open as it passes the saw. Some saws heat unduly on the edges and buckle;

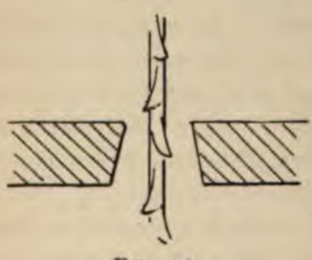


FIG. 343.

this is caused by insufficient set of the teeth, or else the packing in the table groove is too tight; but sometimes also from defective planishing round the edge. This packing is necessary to prevent the saw swerving to one side with the pressure of the cut. Small saws can be driven by foot treadle or by a large hand-power driving wheel, but not for continuous working, unless on very light cuts.

Frame or gang saws in nearly all cases are worked vertically, in imitation of the primitive method of pit sawing. The saw frame is a pair of crossheads connected by two side bars to which the ends of the saw are attached, and are strained tight by bolts. This frame, with its saws, travels up and down in guides, and is driven by a connecting rod and crank from below. The weight of the saw frame and connecting rod is balanced by a weight on the opposite side of the fly-wheel. The speed is about 120 revolutions or double strokes per minute. The timber is bolted by dogs to a travelling frame running on rollers or rails, and is fed up to the saw by a self-acting feed gear, consisting of a pawl and ratchet or pawl and friction grooved wheel, having means of adjusting the travel. The chief wearing parts are the guides and sockets on the saw frame, the brasses of the main shaft and connecting rod, and the rollers of the timber carriage. The latter are seldom of a form or size sufficient to firmly guide the frame, but soon wobble and run loose with a great deal of play. In refitting the saw frame guides their thickness must be carefully regulated to keep the frame perfectly upright and parallel to the guides.

Oiling should be automatic because the sawdust absorbs the oil to a great extent, and on vertical guides it soon runs down and is lost. All slackness of brasses requires to be frequently taken up, or, the speed being high, violent knocking will result. The cut is always made on the down stroke. The saws are made as thin as possible, and tapered off towards the back edge. The correct balancing of the machine is of great importance to its steadiness, and careful adjustment of all the working parts equally essential. Even setting of the saws and accurate spacing at both ends are necessary to

secure clean and easy cutting, and to ensure the safety of the saws.

Repairs to these machines are chiefly confined to the wearing parts mentioned above, but breakages occur in the framing and timber carriage occasionally, which can, however, generally be repaired by wrought-iron plates shaped to fit and secured by set screws, bolts or rivets.

Band saw machines are very popular from their lightness, easy running and general usefulness. The steel endless bands are run over two pulleys faced with leather, which provides an elastic bedding for the saw, and a better grip on it for driving also than the plain cast-iron surface of the pulley. The table is provided with canting motion for cutting on the bevel, and the saw is guided by an adjustable arm carrying two small steel rollers or a socket lined with hard wood, through a slit in which the saw runs. This arm can be fixed to any height to suit the thickness of stuff cut. The lower pulley is the driver, and the cut, therefore, is on the tension side of the saw band. The saw band must be much thicker on the cutting edge than the back, and the teeth set evenly on both sides. It is tightened by drawing the pulleys apart by a screw adjustment to the upper one, which has its axle in a sliding block.

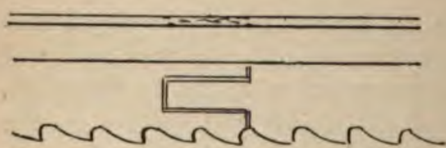


FIG. 344.

The saws frequently break, these breakages being due to various causes—overstraining, forcing the feed too fast or twisting the wood too much for the saw to follow it; hard knots and overheating are other causes, to which may be added uneven temper. To repair them they are brazed by scarfing, or as Fig. 344; in either case the ends are clamped to a flat bar and the brazing done by a lump of white hot metal placed upon the joint on which the rosin and spelter have been sprinkled. These joints, however, are seldom as strong as the original saw band. There is no doubt that many of these breakages would not occur if the upper pulley

was driven also with the lower one, thus taking off a great deal of strain from the saw.

The important points to be observed in running these saws are: (1) not to overstrain them; (2) to see that the pulley bearings are well oiled and that they run with great freedom; (3) to keep the guide close down to the work; and (4) to avoid forcing them to cut faster than they are fairly capable of doing, especially round sharp curves. Besides broken saws these machines are liable to the ordinary wear and tear of brasses and spindles. From their light construction they sometimes get accidentally broken, but not from any cause due to running.

All sawing machines run best on a solid masonry or concrete foundation and should be well bolted down; this greatly

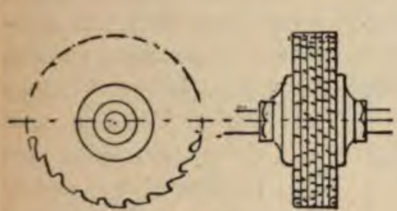


FIG. 345.

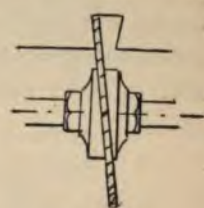


FIG. 346.

reduces vibration and tends to longevity. But it is quite common to find them running on an ordinary floor; in such cases it will generally pay to lay a bed of concrete between and above the floor joists, upon which the machine will run much more steadily and with less noise.

Small saws are used for grooving, and several saws are frequently placed close together on one spindle to cut wide grooves. Cross grooving can be executed this way also (Fig. 345), but the outside saws must have cutting edges to some of the teeth, to cut the cross grain without tearing it. For dovetailing a wobbling saw is a very effective tool (Fig. 346).

Numerous machines are in use for sharpening, re-cutting, gulleting, gumming and setting saws of all shapes and sizes, and perform this work much better than hand labour and at greatly less cost (see p. 384). The actual work is done by

the teeth of the saw, and therefore its teeth, their form and condition, are all important points. For information on these the reader is referred to 'Wood Working Machinery,' by M. Powis Bale, M.I.M.E.; 'Saws,' by Robert Grimshaw, and 'Supplement' to ditto.

CHAPTER XL.

PLANING AND MOULDING MACHINES.

Wood Planers.—Various machines are made for simple planing of one side of stuff, one side and one or both edges, both sides and both edges, and in some cases these are combined with grooving and tongueing cutters or matching cutters, and in other cases with moulding cutters, as for skirtings and architraves. All these operations are performed by rotary cutters, the differences being simply in form and size of cutter. Moulding machines and tenoning machines also perform their work by similar rotary cutters. The cutter heads or blocks are usually square forgings planed all over and bored to fit their spindles, to which they are keyed. Their usual form is as Fig. 347. The cutters are of steel-faced wrought-iron bars, hardened and ground to the proper temperature and well bolted to the heads. They cut in the direction shown in the figure and run at very high speeds, from 800 to 3500 revolutions per minute. At such speeds, though there is not much direct strain on the bearings, these must of necessity be very well fitted. Very long bearings are found best adapted for this class of machine, and

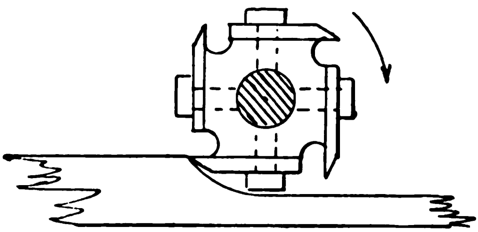
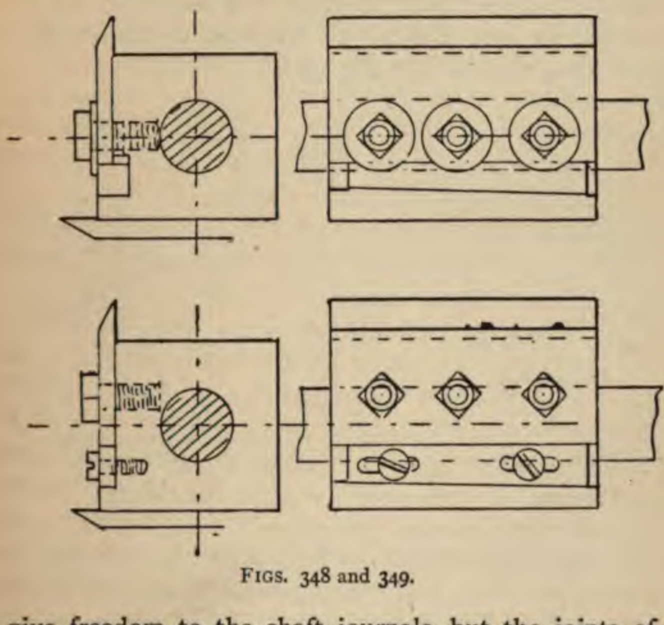


FIG. 347.

they are frequently of gun-metal lined with white metal. The vibration is very great and requires to be met by a substantial base to the machine and a still more substantial foundation. Still there are plenty of such machines fixed on ordinary floors, but their oscillation and noise in such positions are very unsatisfactory and do not tend to efficiency or long life. Every bolt in these machines should have lock nuts, especially those securing the caps of the bearings. These must invariably be bolted down solid, not left slack



FIGS. 348 and 349.

to give freedom to the shaft journals, but the joints of the brasses eased away with a file or scraper till the shaft has just enough freedom when the caps are bolted down hard. This job must be thoroughly done to be effective. There must be no spring in the cutter spindle or its bearings, and the adjustments for raising and lowering require to be free from play and capable of being firmly clamped at any height.

The adjustment of the knives is done by screws or wedges and sometimes by thin packings, but these are objectionable, as indeed are all loose parts or any parts liable to work loose.

The best methods are shown in Figs. 348, 349 and 350, one of which is a screw and the others wedge adjustments. The knives can be easily set to the same radius by revolving the head past a fixed straight-edge. Moulding and fancy cutters are set and worked in the same way as straight cutters, but care must be taken that they all revolve in the same plane, as well as that they project to the same radius. The cutters are best ground to a templet, which must be shaped by taking a diagonal section of the moulding to the same angle as the cutters are fixed on their blocks. The angles of the cutters should be, for soft woods 35°, for hard woods 50° to 55°, and for ploughing 40°, see Fig. 351.

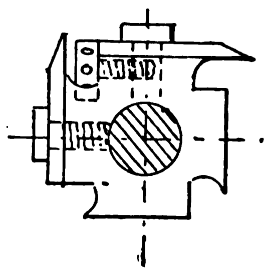


FIG. 350.

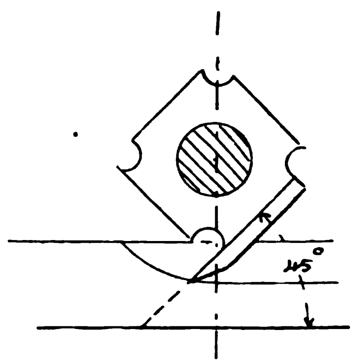


FIG. 351.

The cutter bars should not be less than ¼ inch thick, and for general moulding and planing as much as ⅜ inch is used. The speed should be calculated at the circumference of the cutting circle and varies for different woods.

Very small pulleys are used for driving, and for this reason it is desirable that a second motion countershaft should be used for driving high speed cutters; first, to multiply the speed in two breaks, instead of one; and second, that the fast and loose pulleys may be on this intermediate or second motion shaft, because if on the cutter shaft, the high speed on the loose pulley when the machine is standing is very undesirable, both for the belt and for the machine. Short belts

and guide pulleys for the belts are also objectionable and troublesome.

Panel planers are simple and useful forms of revolving cutter machines: the stuff is held down firmly by hand and passed over the cutter, which projects slightly above the machine table.

General planing machines, also flooring board and matching machines, usually operate on the stuff as it is fed through by rollers, the various pairs of cutters being placed at a short distance in advance of each other, and besides two pairs of feed rollers there are other guide rollers to keep the stuff level, and flat planed surfaces opposite the upper and lower planing cutters to form abutments to the cutters for the stuff to take a bearing against. Any kind of planing or moulding can be done in this way by using separate cutters for each section of the moulded or planed surfaces, and the cutters can be set at any angle for bevelled surfaces. The wearing parts of these machines are the bearings, cutters, spindles, belt pulleys and guide roller spindles, as also belts and feed gear; but the bearings give the greatest trouble, they are liable to heat, and if neglected become so hot as to seize or to melt the white metal. New bearings are very liable to heat, and must be carefully eased and scraped until they run cool, also the oil grooves kept open and the bearings themselves stiff and firm. The pulleys wear a good deal from the slip and heating by the belt at such high speeds; and the belts—from the small diameters of the pulleys they run over and the high speeds—do not last long.

Vertical moulding machines, having a cutter head on top of the vertical spindle, are found extremely useful for moulding round inside frames, on the edges of tables, cantilevers and other shaped or scalloped edges. They do not differ from others except in the arrangement of the parts. The depth cut in is regulated by a templet secured to the piece of stuff operated on, and the edge of the templet runs against a plain collar on the cutter spindle, so as to guide the cutter.

Tenoning machines have a rotary cutter of large diameter, usually built up in sections with plain collars between, of the

thickness of the tenons, the cutters being of the width of the spaces between the tenons, and of course any widths required can be made up by cutters and packings of various thicknesses or widths. The cutter head slides up and down a guide standard, and the work being clamped down to a table, the cutter is brought down through it by a regulated feed gear.

CHAPTER XLI.

VARIOUS WOOD-WORKING TOOLS.

Boring machines are of very simple construction. They consist of a spindle and two bearings, with usually a hand lever for propelling the spindle, which is driven by a long belt pulley of small diameter, and is provided with a simple socket and screw to receive the drills or boring bits. The spindle is either vertical or horizontal, and in some cases, if for special work, capable of being set at any intermediate angle; but usually the work itself can be inclined to the required angle by a swing table. In these machines the spindle and its bearings are the wearing parts, and these offer no special difficulties, but are subject to the same treatment as for other high speed cutters (see p. 395).

Carving machines are a form of boring machines in which the cutter is capable of moving over any part of a surface of wood and keeps revolving; its depth is regulated by a pattern mould and a blunt stylus, which is moved over the mould by hand or by a power feed gear. This motion is conveyed to the boring tool, which therefore cuts away the wood to the same depth as the model.

There are other forms of special wood-working tools embodying one or other of the foregoing initial forms of cutters; but their treatment and management does not require special mention.

Sand-papering machines perform the only other general

operation on wood not yet referred to, except turning, viz. that of grinding or smoothing by abrasion surfaces left more or less rough by the cutting tools described. For flat surfaces a roller covered with sand or glass-paper or cloth is used, or a revolving disc, faced with this material and fixed to a jointed arm, by which it can be moved all over an extensive surface, such as a table top. For many other articles a sand-papered *endless* band, running over two rollers at a short distance apart, is used, the work being applied to the band as it revolves. These machines require no special treatment, except in the frequent removal of the glass-cloth surfaces, which last a very short time.

Mortising machines are the only reciprocating machines used on wood-work, and are seldom worked by power, except in large carriage works, &c. They comprise a vertical spindle reciprocated by a hand lever, which is over-balanced so as always to stand with the spindle at the top of its stroke. The spindle has a tool socket to receive the chisels, and a feather groove running in a guide with a fixed feather, which can be set round by hand to either right or left-hand cutting. The weak point of this machine is the use of a round spindle; it ought to be a V grooved guide, so as to have means of adjustment for wear. As it is, the guide bushes soon wear and become slack and the spindle loose, allowing the chisel to ramble about. The chisels are made with turned taper shanks to fit the socket, and have a small feather or pin to set them square by. They require some care in fitting to the socket, as they must cut exactly to line when turned to either hand; to do this they must, after being fitted to the socket, be heated near the shank, and bent so that by trial in position they can be brought exactly to line each way. The heat must not be allowed to extend to the cutting part to injure the temper.

Wood turning lathes have been referred to (Chapter XXXVIII.) They are made much lighter than for metal-work, and driven at much higher speeds. The great speed causes great vibration, which weight alone would not prevent, so that it is desirable to bolt them to a solid foundation or strut them, to stop the vibration. The fast headstock is usually fitted with

a conical front neck and bush, and either a plain centre hole for the back end of the spindle or another conical neck and bush, with a back thrust screw. The latter is much the best. Cone point bearings wear fast and seldom run true or main-

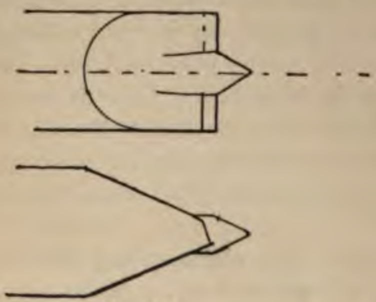


FIG. 352.

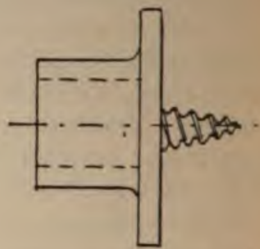


FIG. 353.

tain a circular form. The back centre is often nothing more than a pointed screw with a locking nut or set screw, but a properly constructed sliding centre and screw is much better, as in metal-turning lathes.

The chucks are many and various in shape and fit up. The most useful are: the fork chuck, made as Fig. 352, which

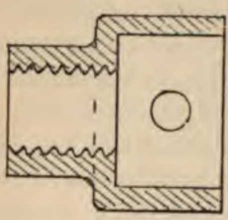


FIG. 354.

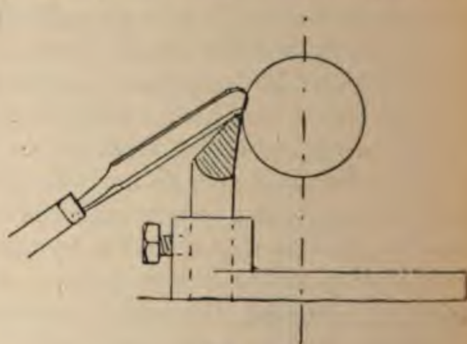


FIG. 355.

is found the best shape in practice; the taper screw face plate (Fig. 353); and the cup or bell chuck (Fig. 354), for which screws are seldom needed, the work being driven into it with a mallet. Several sizes of this chuck are usually required.

A main chuck or face plate is useful to secure large flat pieces to, and a drill chuck to take any kind of boring bits is also required. We have referred to these in detail because most wood turners make them for their own work. In fitting chucks it is always best to make them fit rather loosely on the screw, but to have a good shoulder to fit against the collar on the lathe mandrel, as this bearing ensures their accuracy, and of course they are turned up on the spindle.

The rest is a T piece standing in a vertical socket, and fixed at any angle to the centre line of lathe, or at any height by a set screw. Several T's are required of different lengths, and their section should be as Fig. 355, and if possible the top edge should be planed, as it allows the tool to travel more freely and to cut straighter than with a rough casting.

SECTION X.—*PIPE WORK, FITTINGS, &c.*

CHAPTER XLII.

EARTHENWARE AND METAL PIPES.

PIPE WORK is of universal employment in almost every manufacture and in conjunction with many classes of machinery. We propose to deal here with the practical points of importance in fitting up, repairing and maintaining pipe work and connections for every purpose, as far as is practicable in a general treatise.

Pipes are manufactured of the following materials: earthenware, zinc, tin plate, lead, composition metals, copper, brass and the various bronzes, sheet iron seamed, plate iron riveted or welded, and of wrought iron, drawn, lap or butt welded, of steel and of cast iron, india-rubber, leather and canvas. All these have a multitude of applications and particular advantages of their own to which we shall refer briefly.

Earthenware pipes are used for sewage, laid underground for draining land, buildings, &c., for flue pipes, embedded in the walls of a building or fixed up outside, and for air pipes, to convey air for ventilation or heating.

They are of course brittle and liable to be easily broken, especially at the socket joints, and therefore not suitable for handling, for pressure or for any place where they are liable to accidental blows. The joints are made underground with clay, mortar, fire-clay or Portland cement rammed in the socket after a coil or two of gasket or tarred yarn (Fig. 356). Bends,

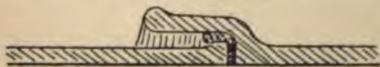


FIG. 356.

Weight of Copper Pipes, per Foot Run.

Bore.	Thickness in Parts of an Inch.						
in.	1/16	1/8	3/16	1/4	5/16	3/8	7/16
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/4	·23	·56	·99	1·51	2·13	2·83	3·64
1/2	·42	·94	1·56	2·27	3·07	3·97	4·96
3/4	·61	1·32	2·13	3·02	4·02	5·11	6·29
1	·80	1·70	2·69	3·78	4·96	6·24	7·61
1 1/4	·99	2·08	2·26	4·54	5·91	7·38	8·94
1 1/2	1·18	2·46	3·83	5·29	6·85	8·51	10·26
1 3/4	1·37	2·84	4·40	6·05	7·80	9·64	11·58
2	1·56	3·22	4·96	6·81	8·75	10·78	12·91
2 1/4	1·75	3·59	5·53	7·56	9·69	11·92	14·23
2 1/2	1·94	3·97	6·10	8·32	10·64	13·06	15·56
2 3/4	2·13	4·35	6·67	9·08	11·59	14·19	16·88
3	2·31	4·73	7·24	9·74	12·53	15·32	18·21

Weight of Brass Pipes, per Foot Run.

Bore.	Thickness in Parts of an Inch.						
in.	1/16	1/8	3/16	1/4	5/16	3/8	7/16
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/4	·22	·53	·94	1·43	2·01	2·68	3·44
1/2	·40	·89	1·47	2·15	2·91	3·75	4·70
3/4	·58	1·25	2·01	2·86	3·80	4·83	5·95
1	·76	1·61	2·55	3·58	4·70	5·92	7·25
1 1/4	·94	1·96	3·09	4·31	5·64	6·98	9·46
1 1/2	1·12	2·34	3·67	5·01	6·49	8·05	9·71
1 3/4	1·33	2·66	4·14	5·70	7·36	9·11	10·94
2	1·48	3·04	4·69	6·44	8·27	10·20	12·21
2 1/4	1·65	3·40	5·23	7·16	9·17	11·27	13·46
2 1/2	1·83	3·75	5·77	7·87	10·06	12·35	14·72
2 3/4	2·01	4·11	6·31	8·59	10·96	13 42	15·97
3	2·19	4·47	6·84	9·31	11·85	14·69	17·42

Weight of Lead Pipes.

Bore.	Length.	Weight of each length in lbs.					
		Common.		Middling.		Strong.	
in.	ft.	Thickness, in.	lbs.	Thickness, in.	lbs.	Thickness, in.	lbs.
½	15	·1	16	·09	22	..	26
¾	15	..	24	..	28	..	36
1	15	·11	30	·15	40	·17	46
1¼	12	..	36	..	44	..	53
1½	12	..	48	..	56	..	70
2	10	·17	56	·21	70	·34	83
2½	10	..	70	..	86	..	100

Weight of Wrought-iron Pipes, per Foot Run.

Bore.	Thickness of Metal in Parts of an Inch.							
in.	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	·21	·5	·9	1·3	1·9	2·5	3·1	3·9
⅜	·3	·7	1·1	1·6	2·3	2·9	3·8	4·6
½	·4	·83	1·4	2·0	2·7	3·5	4·3	5·3
⅝	·46	1·1	1·6	2·3	3·1	3·9	4·9	5·9
¾	·54	1·2	1·9	2·6	3·5	4·5	5·5	6·6
⅞	·6	1·3	2·1	2·9	3·9	4·9	6·1	7·3
1	·7	1·5	2·4	3·3	4·3	5·5	6·7	7·9
1¼	·87	1·8	2·9	3·9	5·2	6·4	7·8	9·3
1½	1·0	2·1	3·3	4·7	5·9	7·4	8·9	10·6
1¾	1·2	2·5	3·8	5·3	6·8	8·4	10·1	11·9
2	1·4	2·8	4·3	5·9	7·6	9·5	11·3	13·2
2¼	1·53	3·1	4·8	6·6	8·5	10·4	12·4	14·5
2½	1·7	3·5	5·3	7·3	9·3	11·4	13·6	15·9
2¾	1·9	3·8	5·8	7·9	10·1	12·4	14·7	17·2
3	2·03	4·1	6·3	8·6	10·9	13·3	15·9	18·5

CAST-IRON PIPES.

Table showing Safe Thickness of Metal in Inches and Weight per Length in Lbs., including Sockets for Different Sizes of Cast-iron Pipe under Various Heads of Water.

Bore in Inches.	25 Feet Head or 10·82 lbs. Pressure.		50 Feet Head or 21·65 lbs. Pressure.		100 Feet Head or 43·30 lbs. Pressure.		150 Feet Head or 64·85 lbs. Pressure.		200 Feet Head or 86·60 lbs. Pressure.		250 Feet Head or 108·25 lbs. Pressure.		300 Feet Head or 129·90 lbs. Pressure.	
	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.
2	·225	54	·2946	63	·3126	67½	·3306	72	·3486	76½	·3666	81	·3846	86
3	·320	132	·3449	144	·3539	149	·3629	153	·3719	157	·3809	161	·3900	166
4	·335	180	·3612	197	·3732	204	·3852	211	·3972	218	·4092	226	·4212	235
6	·375	300	·3938	315	·4118	330	·4298	345	·4478	361	·4658	377	·4838	393
8	·433	456	·4224	445	·4504	475	·4744	502	·4984	529	·5224	557	·5464	584
10	·442	576	·4590	600	·4890	641	·5190	682	·5490	723	·5790	766	·6090	808
12	·446	720	·4916	768	·5276	826	·5636	885	·5996	944	·6356	1004	·6716	1064
14	..	..	·5242	952	·5662	1031	·6082	1111	·6502	1191	·6922	1272	·7342	1352
16	..	..	·5801	1215	·6048	1253	·6528	1360	·7008	1463	·7488	1568	·7968	1673
18	..	..	·5894	1370	·6434	1500	·6974	1630	·7514	1761	·8054	1894	·8594	2026
20	..	..	·6220	1603	·6820	1763	·7420	1924	·8020	2086	·8620	2248	·9220	2412
24	..	..	·6870	2120	·7592	2349	·8312	2580	·9032	2811	·9752	3045	1·0472	3279
30	..	..	·7850	3020	·8750	3376	·9650	3735	1·0550	4095	1·1450	4458	1·2350	4822
36	..	..	·8828	4070	·9908	4581	1·0988	5096	1·2068	5613	1·3148	6133	1·4228	6656
48	..	..	1·0784	6616	1·2224	7521	1·3664	8431	1·5104	9340	1·6544	10269	1·7600	11195

All pipes cast in lengths of 9 feet, except the 2-inch, which are cast 6 feet long.

elbows, tees or branches are formed in special pipes, and cannot be cut out of main pipes. There are many varieties of "specials" for reducing diameters, branching out small services from large ones at any angle, forming S traps and other purposes. There are also pipes made in halves longitudinally to enable a length to be taken out and a branch piece inserted, or a length of the pipe cleaned out through the aperture. Cutting is performed by a chisel, with which is carefully nicked a groove all round the pipe, until the piece is separated by light blows. Fixing earthenware pipes is a simple operation. The points to be observed are these: the ground beneath them should never be disturbed, and the trench, in fact, cut only just deep enough, the pipes, after laying and jointing, to be well packed underneath to prevent

FIG. 357.

FIG. 358.

FIG. 359.

any settlement or displacement in filling in over them. They are always laid to a fall for drainage. This is done by a long straight-edge level laid on the pipes, or by a telescope or sighting level above ground and a depth rod.

Zinc and tin plate pipes are made from sheets bent round a mandrel or former and soldered, and are not much used. Zinc pipes have a limited application as drain pipes for rain water and as air pipes for ventilation. Bends must be formed by mitres (Figs. 357 and 358), cut by a mitre block and saw, unless the pipe is very large, when it can be dipped in water to half the angle of the bend required, and the surface or wetted line will be the correct line of cut required. Tees or branches are formed by cutting the branch pipe to the curve or sweep of the main pipe and soldering together, with or

without a strengthening flange (Fig. 359), which can also be cut out of the sheet metal.

Repairing such pipes is effected chiefly by patches soldered on, unless the pipes are too rotten to stand the solder and handling, when a new pipe or part length is fitted in.

Lead and composition pipes have very extensive applications as water and gas services throughout buildings, also as speaking tubes, bell wire tubes, &c. They are seldom used

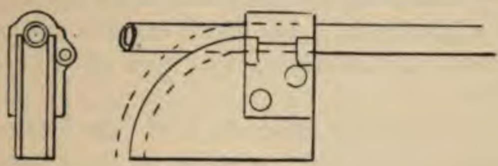


FIG. 360.

for pressures greater than 100 lbs. per sq. inch, and are so easily bent to fit in almost any conceivable irregular line, that they are almost exclusively used in buildings for water and gas. Their disadvantages are: bursting by frost when full of water, contamination of the water by the oxidation of the lead; and they are not so easy to joint as iron, brass or copper pipes, as nothing but solder is effective except for very

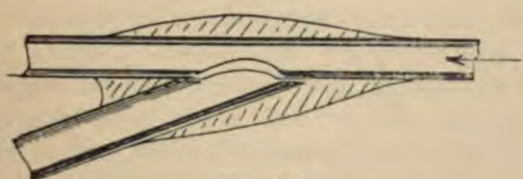


FIG. 361.

light pressures, when rubber tube can be used in particular instances. They can be bent, especially the stronger sections, to very short angles without cracking, but the thin sections are liable to flatten a good deal, which can be partially prevented by bending round a grooved templet (Fig. 360). Flattening of course reduces the effective sectional area of the pipe and its efficiency. Branches are simply soldered to the main pipe, generally at right angles, but it is much better

to set them at an acute angle to the main pipe, as Fig. 361. All other connections, as taps, unions, &c., are soldered.

The pipes should always be laid so as to have such a fall to one point that all condensed moisture, in the case of gas or air pipes, will drain to some convenient point where it can be drawn off or run back to the main, or—in the case of water pipes—where the entire pipe can be emptied by a tap. Thin pipes are also made for speaking tubes, of a mixture approximating to type metal, much harder than lead, capable of slight bending, but which must be also soldered at all short bends and branches; it is used chiefly for speaking and air tubes.

Repairs to lead pipes generally arise from bursts or cracks, resulting chiefly from frost or water hammer from defective fittings, occasionally from looseness near a tap, which by its constant springing ultimately develops a crack or flaw in the pipe. When used for hot water they also become furred and choked, especially at bends or low places in the line of pipe. Cracks can be soldered if the pipe can be dried properly first, but in other cases a new piece is inserted and soldered up. For details of the art of plumbing, see 'Plumbing,' by W. B. Buchan.

Copper, Tin, Brass and Bronze Pipes.—These have fewer applications than either iron or lead, but in particular cases cannot be replaced by any other metals. They are made of a variety of alloys, ranging in hardness from soft copper to that of wrought-iron, and are both drawn solid or have brazed seams. Drawn copper pipes are easily bent to nearly the same angles as lead pipe after annealing, and are useful for many purposes, as drain pipes, oil pipes, &c., in machinery, for which small sizes are used. Their ends can be screwed and thus attached to various fittings without soldering or brazing, but tolerably stout sections only should be used in this way.

Large copper pipes for steam pipes, &c., are always formed by hammering and annealing from sheets, and are carefully brazed at the joints and to flanges, by which all connections are made. All such pipes, to stand pressure, should be tested to at least eight times the pressure, as the failure of

such a pipe is a most disastrous accident; in fact it is becoming customary now to replace them with mild steel riveted pipes. Copper pipes are used for water and beer, and are tin-lined. Block tin pipes are, however, to be preferred. Brass pipes can be also screwed at the ends for attachment of fittings, but to a special fine thread only; lighter sections for telescope tube, &c., being chased in the lathe. Brass tubes cannot be bent, however, and branches or tees must be soldered or brazed to the main pipe, or to a T-piece inserted where required. They are extensively used for boiler and condenser tubes, in diameters from ½ inch to 2½ or 3 inches. When they fail it is chiefly by splitting or cracking; this can sometimes be repaired by soldering, or soldering a patch over. Brass and bronze tubes have also numerous applications, as liners for pumps, rams or plungers and rods, bodies for lubricators, and many other similar uses. They are not suitable for water service because they corrode into verdigris, but are used largely for gas fittings.

CHAPTER XLIII.

IRON PIPES AND FITTINGS.

Iron and Steel Riveted Pipes.—These are made now from sheets and plates of from No. 24 W.G. up to ½ inch thick, and in diameter from 3 inches up to 6 feet if required. Sheet iron is much employed for flue pipes, hot air flues, ventilating tubes, &c., and is either seamed or riveted. Riveting is easiest done with copper rivets, and care must be exercised not to strike the pipe or it will warp and draw the tube seam out of shape. These flue pipes are jointed by tapering each length sufficiently for one end to socket over the other, also by using short bands or ferrules riveted on one end, forming sockets for the other or plain ends. The lap and rivets

always prevent a good joint being made, however, and if required air tight they must be provided with L flanges riveted on; galvanising helps to close up all the leaks. Bends, or rather elbows, are formed as described for zinc pipes (page 406), but instead of soldering they are folded as Fig. 362, by beating with a hard wood or copper hammer; but the very best charcoal iron must be used for these purposes. Riveted

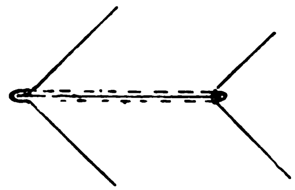


FIG. 362.

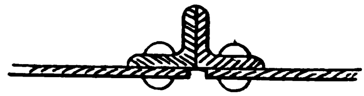


FIG. 363.

pipes for pressure are, however, a boiler maker's job, and require to be well and closely riveted and caulked, Figs. 363 and 364. For great pressure double riveting is used, and for large pipes double riveted butt joints. The flanges are welded or solid rolled rings of L iron, and are riveted and caulked to the ends of the pipes and faced in the lathe; such pipes will stand enormous pressures, are not liable to breakage and are comparatively very light, but expensive, unless the principle that "the best is the cheapest" be adopted. The best protection to all such pipes is to dip them hot into a tank of Dr. Angus Smith's composition, which forms a hard, bright and thick varnish on them, which will resist air or water for very long periods.

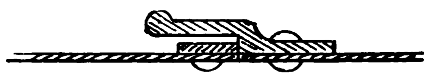


FIG. 364.

In a line of such riveted pipes the bends are usually of cast iron of proportionate strength. Wrought-iron or mild steel bends can be made, too, but are necessarily very costly. Tees or branches are formed on the main pipes either by inserting a cast-iron special pipe with the branch cast on, or by riveting a cast-iron block on with a sweep flange

Wrought-iron or steel blocks with curved flanges can, however, now be obtained, moulded by the hydraulic press in one piece, with flanges, and are much used also for boiler manholes. Flanged joints are most generally used, but socket joints are preferred in certain cases, as being more elastic (Fig. 364). Flanged pipes, however, are much easier to take out to repair than socket ones.

Wrought-iron and Steel Gas, Water and Steam Pipes.—This is the most extensively used class of pipes, possessing, as they do, most of the qualifications of all the others ; they are employed to convey air, steam, water and other fluids at pressures up to 5 tons per square inch, and are made in various strengths, distinguished as gas tube, steam tube, boiler tube and hydraulic tube. Screwed joints are invariably used, but these are often fitted with flanges, because with flanges the pipes are easier to detach or disconnect at any particular point —in fact, when sockets are used and a long line of pipes is fixed, it is desirable to insert a flange joint at various points for facility of disconnection. Screwed running joints or long screws are often used for this purpose, but are difficult to make tight, as the loose coupling allows the fluid to leak towards the back nut and is only kept in by screwing up the latter with red lead and a grummet.

Wrought-iron pipes can be bent to almost any curves by heating, but are liable to split, especially at the weld. Separate bends and other fittings are therefore always used if possible, and bending the pipe only adopted for a set off or slight angle, and the longest lengths of pipe available should be used to reduce the number of joints, all or any of which may leak and are also sources of obstruction to the flow of water. Square elbows should never be used—round elbows are made that will go into as little space and give better results. A mixture of red and white lead in about equal parts, softened into a thickness equal to treacle, is the best for jointing, and laid on the threads with a brush ; whenever it is necessary to unscrew such a joint after making, always retouch it with the red lead cement, as the unscrewing breaks its hold. It is best not to disturb such joints after making

by tightening up others further on, but to hold the pipe already fixed by a pair of tongs while tightening up the next length. Tees should be inserted wherever there is the least probability of a branch being wanted at any future time, and closed up by a plug till wanted. The pipes require to be laid as stated for lead pipes (p. 408), with a fall, to enable them to be drained off.

Tongs often crush and crack a thin pipe by digging into it at one point of grip only; such old pattern tools are now generally replaced by others which do less injury to the pipes. Adjustable tongs are very useful, enabling a considerable range of pipes to be screwed up with a single tool.

Cutting is almost always performed by the rotary pipe

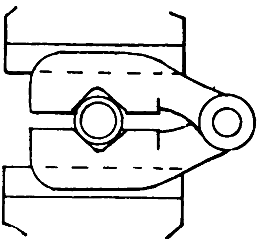


FIG. 365.

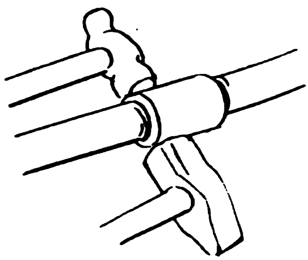


FIG. 366.

cutter wheel, but sometimes by a file; the cutter wheel leaves a burr or thickening which should be filed off before screwing.

Screwing is done by hand die-stocks, hand screwing machines and power machines. Special vices are used to hold pipes also, having a double V grip; they should not be held in a common vice unless false V jaws are employed, as Fig. 365, as the flat grip of the vice flattens and often splits the pipe.

Galvanising protects the pipe effectually from rust and internal corrosion also for a long time; ordinarily, however, the pipes are painted on the outside. Considerable difficulty is often found in unscrewing old pipes from corrosion; the best plan for loosening them is hammering around the threaded part, as Fig. 366, holding up a heavy hammer to give effect

to the blow; this expands the iron and breaks its joint so that it can be unscrewed.

Wrought-iron pipes are also used for hand railing and guide rods, when it is usual to employ internal unions either screwed or pin riveted.

Large pipes for steam and water should, if possible, have flanges at intervals if not at all the joints.

Coupling joints which leak can be caulked by a caulking chisel (Fig. 367), if it is undesirable to unscrew them; this happens mostly in pipes of large diameter, which are often anything but round even in the threaded ends, as these spring more or less in the screwing machine. Too much lead used in making a joint will often squeeze out into the bore of pipe and nearly choke it.

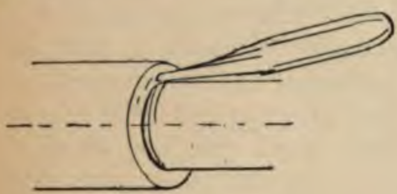


FIG. 367.

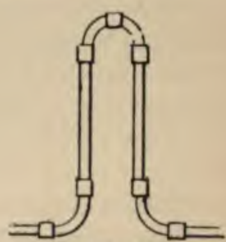


FIG. 368.

In long lengths of pipes provision must be made for expansion, especially with hot water or steam; bends generally provide sufficiently for this, but where there are none an expansion piece or an inverted U piece must be inserted at intervals of, say 100 feet (as Fig. 368). The expansion of steam pipes amounts to 1 inch in 50 feet.

The strength of the pipe should always be proportioned to the pressure, *gas* pipes or fittings should not be used for steam or water, and steam pipes and fittings are not suitable for pressures over 200 lbs. per square inch. Heavier sections can be obtained, hydraulic pipes being made in three or four strengths, for pressures up to 5 tons per square inch.

The joining of hydraulic pipes and fittings, though exactly similar to gas and steam, is more effectively done, because the pipes are stronger and do not spring or become distorted at

the joints by flattening, &c. Flange joints must be turned and recessed as Figs. 136 and 137, p. 107; plain rough surfaces, as used for gas and steam, will not be tight under high pressures, and mere grip friction is not enough to prevent the jointing material blowing out. Leather is generally used up to say 1000 lbs. per square inch, but for heavy pressures gutta-percha or lead cord sunk in the groove is the best. There must be no break in these cords; if of lead they must be soldered at the joint; and if of gutta-percha are easily softened by heat, and welded while soft by the fingers. Large bends, and as few as possible, should be the rule in hydraulic pipe work. Air vessels are seldom needed, because the pipe expands to the pressure sufficiently, as a rule, unless very short.

In repairing wrought-iron pipe work the foregoing memoranda need be borne in mind, and if adhered to will save trouble and annoyance. These pipes corrode internally, sometimes to a surprising extent, due to the foul or lime-saturated condition of the water, or the effect of steam and boiler primage. Hot-water pipes corrode worst of all, especially where the circulation is sluggish, so much so that such pipes, when taken out, often cannot be looked through, the corrosion, in irregular lumps and masses, nearly chokes them. Such pipes should be of much larger diameter than is sufficient to convey the water, and laid with a good fall to allow the sediment to settle towards the boiler. Cutting them out is often necessary when they cannot be unscrewed, or there is no flange or running joint where they may be disconnected. To do this, cut one of the sockets open by a chisel rather than try to cut the pipe in two.

As a rule no pipe of less diameter than $\frac{3}{8}$ inch should be used for steam, or less than $\frac{1}{2}$ inch for cold water, nor less than 1 inch for hot water. Any size may be used for gas.

In fitting up a set of pipes, by far the best plan is to make a correct drawing with measurements of the whole affair, and cut and fit it all at the workshop. A poor workman, instead of doing this, will make several journeys to the job to mark off every length required as he proceeds; others carry a whole

workshop to the place, and fit it up there, indifferently supplied —as they must, after all, be—with plant, and frequently send to the workshop for various articles required, thus losing a lot of time.

Cast-iron Pipe Work.—This greatly resembles that of earthenware (p. 402), except that, though more breakable than wrought-iron, cast-iron pipes are still very strong, and in the fact that the joints are made with lead run in and caulked, otherwise the general conditions and structure are very much the same. For underground work socket pipes are invariably used. They must be laid on a solid bed not liable to settlement; the bends, elbows, &c., are all separate castings, but small wrought-iron pipes can be attached to or branched from the mains by drilling and tapping them. Special ratchet drills and taps are made for doing this. The best pipes have turned spigots and bored sockets, which, while they are not water-tight themselves as a joint, yet are nearly so, and serve as a better backing than yarn for the lead tamping. They do not corrode so readily as wrought-iron pipes, and the best protection yet adopted is dipping them hot into Dr. Smith's composition, which dries hard and glossy, almost like earthenware glaze. For special jobs pipes can be obtained lined with earthenware glaze, but must not be hammered, or it will crack and scale off.

Flanged cast-iron pipes are, however, chiefly used for engineer's work, and the joints made with rubber insertion or leather rings; tarred yarn grummets and red lead paste are also much used. Asbestos millboard and composition rings and joints are also used for hot water and steam. Bolts are invariably used to secure the flanges; set-screws and studs are unreliable. The flanges should always be faced in the lathe. In fixing a line of such pipes, the important points to be observed are, proper support, so that no strain is thrown on the bolts and flanges, and allowance for expansion. Cast iron must not be depended on to spring much, and not at all in lengths of less than 20 feet, so that bends and angles do not afford, generally speaking, sufficient elasticity for expansion, and proper expansion joints must be inserted at least every

100 feet in lines of straight pipe. The pipe should always be laid to fall towards the boiler, or a steam trap if for steam. If for hot water, it should have one lowest point where it can be emptied by a tap.

DIMENSIONS OF PIPES USED AT THE GLASGOW WATER-WORKS.
(J. F. Bateman, Engineer.)

Bore of pipe.	Length of each pipe.	Thickness of metal.	Weight.				Working head.	
			Per pipe.			Per foot run.	Feet of water.	Lbs. per square inch.
in.	ft.	in.	cwt.	qrs.	lbs.	cwt.		
33	12	1	39	1	25	3·29	210	91
30	12	1¼	44	0	3	3·67	300	130
30	12	1	35	3	5	2·98	230	100
24	12	1	28	1	23	2·37	300	130
20	9	7/8	16	0	4	1·78	270	118
20	9	3/4	13	3	25	1·55	240	104
18	9	13/16	13	1	12	1·48	300	130
18	9	3/4	12	1	19	1·38	260	113
18	9	11/16	11	1	27	1·27	230	100
16	9	3/4	10	3	27	1·22	300	130
16	9	11/16	10	0	18	1·13	250	108
16	9	5/8	9	1	9	1·04	200	86
15	9	11/16	9	2	3	1·06	270	118
15	9	9/16	7	3	25	·88	180	78
14	9	11/16	8	3	23	·99	290	125
14	9	5/8	8	0	25	·91	250	108
14	9	9/16	7	2	0	·83	200	86
12	9	5/8	6	3	13	·76	290	125
12	9	9/16	6	0	26	·693	240	104
10	9	9/16	5	0	16	·571	300	130
9	9	9/16	4	2	24	·524	300	130
8	9	1/2	3	2	23	·412	300	130
7	9	1/2	3	1	1	·362	300	130
6	9	7/16	2	1	27	·277	300	130
5	9	13/32	1	3	24	·218	300	130
4	9	3/8	1	1	20	·158	300	130
3	9	3/8	1	0	10	·121	300	130
2	6	3/8	0	2	4	·089	300	130

Note.—The length does not include the length of the socket.
The weight includes the weight of the socket.
The proof strain is double the working head.
Permitted deviation from weight:—

2	per cent. in pipes from		20 to 33	in. bore.
2½	,,	,,	13 to 18	,,
3	,,	,,	8 to 12	,,
4	,,	,,	2 to 7	,,

Pipes exceeding 18 inches bore to be cast socket downwards.

All *cast*-iron pipes require testing before using, as they frequently have pin-holes, cold shuts, &c. where they may leak, and to repair these after fixing is very difficult. They can generally be repaired by drilling and plugging with screwed

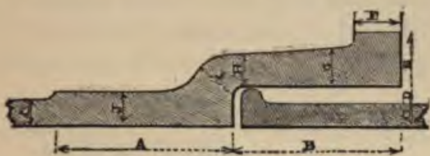


FIG. 369.

plugs, unless the flaw is extensive, when the pipe must be discarded ; caulking is of very little use.

Flanges are seldom made strong enough ; their thickness should always be at least twice that of the pipe ; and for heavy pipes they should be bracketed also between the bolt-holes, and the internal angle well rounded.

STANDARD DIMENSIONS OF SOCKET PIPES.

LEAD JOINTS. (Fig. 369.)

Bore, inches.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
2	3	3	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$
3	3	3	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$
4	3	3	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$
5	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$
6	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$
7	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$
8	4	4	$\frac{1}{2}$	$\frac{3}{8}$	$1\frac{1}{8}$	1	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$
9	4	4	$\frac{9}{16}$	$\frac{3}{8}$	$1\frac{1}{8}$	1	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$
12	4	4	$\frac{5}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$	1	$\frac{15}{16}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{3}{4}$
15	$4\frac{1}{2}$	$4\frac{1}{2}$	$\frac{11}{16}$	$\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$1\frac{1}{16}$	$\frac{13}{16}$	$1\frac{1}{4}$	$\frac{7}{8}$
18	$4\frac{1}{2}$	$4\frac{1}{2}$	$\frac{13}{16}$	$\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{8}$	1	$1\frac{1}{4}$	1
20	$4\frac{1}{2}$	$4\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{8}$
24	5	5	1	$\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{8}$
33	$5\frac{1}{2}$	5	1	$\frac{3}{8}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{5}{16}$

For hydraulic purposes very heavy sections are used, with very thick oval flanges, faced and turned with joint as shown on p. 107, and strong bolts are used, the flanges laid horizontally (if the pipes are underground, to allow for slight settlements), and gutta-percha cord used for jointing material.

Water pipes laid underground become, in time, almost choked with combined sediment and corrosion, due to the fact

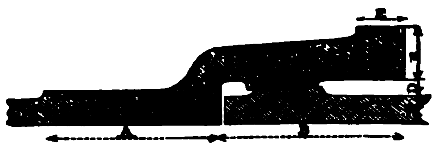


FIG. 370.

that during the nights the water is quiescent and deposits its sediment. The water current does not flow in a straight line, but in eddies and swirls that allow spots to accumulate and grow until they partially close the bore. After a time these pipes fail to give anything like the supply their diameter would warrant, and they have to be taken up, when it is often found that their effective diameter has been reduced two-thirds. This involves renewal, not repair.

TURNED AND BORED JOINTS. (Fig. 370.)

Bore, inches.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.
2	3	3	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$
3	3	3	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$
4	3	3	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$
5	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$
6	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$
7	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$
8	4	4	$\frac{1}{2}$	$\frac{3}{8}$	$1\frac{1}{8}$	1	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$
9	4	4	$\frac{9}{16}$	$\frac{3}{8}$	$1\frac{1}{8}$	1	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$
12	$4\frac{1}{4}$	$4\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$	1	$\frac{15}{16}$	$\frac{13}{16}$	1	$\frac{3}{4}$	$1\frac{3}{4}$

Taper of bored portion $\frac{1}{32}$ inch per inch of length.

Strength of Cast-iron Pipes.—The average tenacity of cast iron used for water service pipes is 18,500 lbs. per square inch. Taking the factor of safety at $3\frac{1}{3}$, the highest safe tension is 5,500 lbs. per square inch. Allowance must, however, be made for irregular thickness of pipes, stresses due to hydraulic shock, bending stress from pressure of earth above or settlement of earth below the pipes. For these three times the actual pressure should be calculated for, thus giving for factor of safety, $3\frac{1}{3} \times 3 = 10$; and the greatest safe stress due to actual pressure in the pipe $=$ 1,850 lbs. per square inch.

All pipes used for water mains are tested to a pressure equal to a head of water of 500 feet, or 216 lbs. per square inch.

The proportions given in the following table are for water or exhaust pipes where there is but little pressure or strain.

PROPORTIONS OF CAST-IRON FLANGED PIPES.

Internal Diameter of Pipe.	Thickness of Metal.	Thickness of Flanges.	Diameter of Flanges.	Diameter of Bolt Circle.	Number of Bolts.	Diameter of Bolts.
2	$\frac{5}{16}$	$\frac{9}{16}$	$6\frac{1}{2}$	$4\frac{7}{8}$	4	$\frac{5}{8}$
$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{8}$	7	$5\frac{1}{4}$	4	$\frac{5}{8}$
3	$\frac{7}{16}$	$\frac{5}{8}$	8	6	4	$\frac{5}{8}$
$3\frac{1}{2}$	$\frac{7}{16}$	$\frac{11}{16}$	$8\frac{1}{2}$	$6\frac{1}{2}$	4	$\frac{5}{8}$
4	$\frac{1}{2}$	$\frac{3}{4}$	9	7	4	$\frac{5}{8}$
$4\frac{1}{2}$	$\frac{1}{2}$	$\frac{13}{16}$	$9\frac{1}{2}$	$7\frac{1}{2}$	4	$\frac{3}{4}$
5	$\frac{1}{2}$	$\frac{13}{16}$	10	8	5	$\frac{3}{4}$
6	$\frac{1}{2}$	$\frac{7}{8}$	12	$9\frac{5}{8}$	6	$\frac{3}{4}$
7	$\frac{9}{16}$	$\frac{7}{8}$	13	$10\frac{3}{4}$	6	$\frac{3}{4}$
8	$\frac{9}{16}$	$\frac{15}{16}$	$14\frac{1}{2}$	12	6	$\frac{7}{8}$
9	$\frac{5}{8}$	1	$15\frac{1}{2}$	13	7	$\frac{7}{8}$
10	$\frac{5}{8}$	1	17	$14\frac{1}{2}$	7	$\frac{7}{8}$
11	$\frac{5}{8}$	$1\frac{1}{16}$	18	$15\frac{1}{2}$	8	1
12	$\frac{3}{4}$	$1\frac{1}{8}$	19	$16\frac{1}{4}$	8	1
13	$\frac{3}{4}$	$1\frac{1}{8}$	21	$17\frac{1}{2}$	9	1
14	$\frac{3}{4}$	$1\frac{1}{8}$	22	19	10	1
15	$\frac{13}{16}$	$1\frac{1}{4}$	$22\frac{1}{2}$	$19\frac{1}{2}$	10	1
16	$\frac{13}{16}$	$1\frac{1}{4}$	24	21	11	1
18	$\frac{7}{8}$	$1\frac{5}{16}$	$26\frac{1}{2}$	$23\frac{1}{2}$	11	$1\frac{1}{8}$
20	$\frac{15}{16}$	$1\frac{3}{8}$	28	$25\frac{1}{4}$	11	$1\frac{1}{8}$
21	$\frac{15}{16}$	$1\frac{3}{8}$	30	$27\frac{1}{4}$	12	$1\frac{1}{8}$
22	$\frac{15}{16}$	$1\frac{3}{8}$	32	$29\frac{1}{4}$	14	$1\frac{1}{8}$
24	1	$1\frac{1}{2}$	$33\frac{1}{2}$	$30\frac{3}{4}$	14	$1\frac{1}{8}$
26	1	$1\frac{1}{2}$	$35\frac{1}{2}$	$32\frac{3}{4}$	15	$1\frac{1}{8}$

Friction of Water in Pipes.

Friction loss in pounds pressure per square inch, for each 100 feet of length in clean iron pipes discharging given quantities of water per minute.

Imperial Gallons.	Sizes of Pipes—Inside Diameter.														
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.
4	3·3	0·84	·31	·12											
8	13·	3·16	1·05	·47	·12										
12	28·7	6·98	2·38	·97	·27										
16	50·4	12·30	4·07	1·66	·42										
20	78·	19·00	6·40	2·62	·67	·21	·10								
25	..	27·5	9·15	3·75	·91	·30	·12								
29	..	37·	12.4	5·05	1·26	·42	·14								
33	..	48·	16·1	6·52	1·60	·51	·17								
37	..	..	20·2	8·15	2·01	·62	·27								
41	..	..	24·9	10·00	2·44	·81	·35	·09							
62	..	..	56·1	22·40	5·32	1·80	·74	·21							
83	..	..	..	39·	9·46	3·20	1·31	·33	·05						
104	..	..	..	48·1	14·9	4·89	1·99	·51	·07						
125	..	..	..	..	21·2	7·00	2·85	·69	·10	·02					
145	..	..	..	..	28·1	9·46	3·85	·95	·14	·03					
166	..	..	..	..	37·5	12·47	5·02	1·22	·17	·05	·01				
208	..	..	..	..	47·7	19·66	7·76	1·89	·26	·07	·03				
250	..	..	..	..	..	28·06	11·20	2·66	·37	·09	·04	·005			
291	..	..	..	..	..	33·41	15·20	3·65	·50	·11	·05	·007			
332	..	..	..	..	..	42·96	19·50	4·73	·65	·15	·06	·01			
375	..	..	..	..	..	..	25·00	6·01	·81	·20	·08	·02			
415	..	..	..	..	..	..	30·80	7·43	·96	·25	·09	·04	·017	·009	·005
625	..	..	..	..	..	..	..	14·32	2·21	·53	·18	·08			
830	..	..	..	..	..	..	..	..	3·88	·94	·32	·13	·062	·036	·020
1040	..	..	..	..	..	..	..	..	..	1·46	·49	·20	·091	·049	·028
1250	..	..	..	..	..	..	..	..	..	2·09	·70	·29	·135	·071	·040
1455	..	..	..	..	..	..	..	..	..	..	·95	·38			
1665	..	..	..	..	..	..	..	..	..	..	1·23	·49	·234	·123	·071
1875	..	..	..	..	..	..	..	..	..	..	..	·63			
2080	..	..	..	..	..	..	..	..	..	..	..	·77	·362	·188	·107
2500	..	..	..	..	..	..	..	..	..	..	..	1·11	·515	·267	·150
2915	..	..	..	..	..	..	..	..	..	..	..	..	·697	·365	·204
3330	..	..	..	..	..	..	..	..	..	..	..	..	·910	·472	·263
3750	..	..	..	..	..	..	..	..	..	..	..	..	..	·593	·333
4165	..	..	..	..	..	..	..	..	..	..	..	..	..	·730	·403
5000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	·585

The frictional loss is greatly increased by bends or irregularities in the pipes.

India-rubber, Leather and Canvas Pipes supply the flexible sorts of connections required in certain cases. There are also flexible coiled metal pipes and the sphincter-grip hose, which is protected and strengthened by wire coils: these all have

their special uses. We need only note that they are not suitable for very heavy pressures, although such pressures as from 500 to 700 lbs. per square inch are sometimes used with them. Rubber pipes must not be in contact with oil, which rots them into a paste. Leather hardens and becomes brittle, and requires to be oiled or saturated with grease. All short bends, creases or twists must be avoided, as at these points they soon crack. Connections are best attached by whipping with copper wire closely laid and drawn tight at each coil. Leather must not be used for hot water or gas, and rubber does not last long with steam or hot water. External strengthening with wire is better than internal in every way, and the wire should not be of too small a gauge. Repairs usually mean renewals, or at least partial renewals, by inserting new lengths in place of damaged ones.

CHAPTER XLIV.

TANKS AND CISTERNS.

IN connection with pipe work these are largely used and under various circumstances, as service or supply tanks, as circulating tanks, and as heating tanks. They are constructed of wood, of wood lined with zinc or lead, of copper or zinc sheets, of wrought-iron plate riveted, and of cast-iron plates bolted together.

Wood tanks for cold water, if well made, are very serviceable. The wood should be of fair thickness, never less than one inch, all joints grooved as Fig. 372, and held securely by *outside* long bolts and nuts. In putting together—the boards being first tongued and grooved—all the joints are well coated with thick white lead and boiled oil, laid on by a brush: the only care needed afterwards is to keep them wet; if allowed to dry they shrink and crack.

Wood tanks constructed in this way are also frequently

lined with lead or zinc, jointed at the angles by soldering *in situ*, the corners receiving particular attention. Connecting pipes should be of lead passed through and soldered inside. A lead cistern thus made is the most durable of any. If it fails it is found to be due to want of cleansing; the mud sometimes acts on small spots and eats into the metal, but this happens much more frequently with zinc.

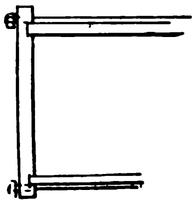


FIG. 371.

Copper cisterns are rare, but as circulating vessels for hot water they are much used, and outlast several iron ones as a rule. They are of sheet copper of about No. 16 to 20 W.G., and riveted and soldered at the lap joints. Any leaks in these generally occur at the angles, and can usually be soldered or patched over.

Wrought-iron tanks are very numerous; the modern plan of galvanising them whole has given them a position and impetus in the trade that no other construction ever had; they are riveted together generally without L iron angles, by bending the plate itself. Their failures are generally due to want of cleaning out. The deposit eats through the zinc surface and soon

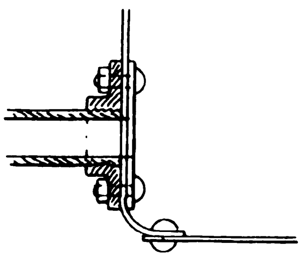


FIG. 372.

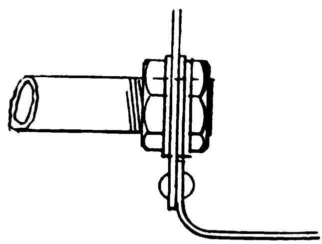
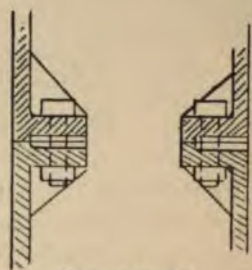


FIG. 373.

destroys the iron bottom. They cannot be repaired as a rule, and, being cheap, are usually renewed. Large tanks require cross tie bolts to prevent the sides bulging. Connections are generally made by flanges inside and out, or by pipes with washers and back nuts, Figs. 372 and 373.

Cast-iron tanks are made of flanged plates bolted together,

and the joints between the plates caulked. In some tanks the flanges are outside, as Fig. 374, in others inside, as Fig. 375. In the latter plan the bolts are in the water and soon become destroyed by corrosion, but such tanks are more sightly exteriorly than the others. The caulking is always done from the outside, and consists of thick strands of tarred yarn steeped in red lead and boiled oil, driven in with a caulking tool till the joint is full. Rust joint cement is also used in the same way—prepared by mixing cast-iron borings with water containing sal-ammoniac in solution, mixed *warm* into a paste—in small quantities as wanted. Some of the best tanks, however, have planed joints, and are simply bolted together with strips of canvas soaked in red lead and boiled oil, or red lead putty alone. Connections are either of wrought-iron pipe tapped into the plates, or, if of cast iron, flanged pipes are used and they are bolted up with bolts and rubber rings to the tank plates.



FIGS. 374, 375.

Regular and systematic cleansing is essential to the life of tanks of all kinds, the bottoms should be thoroughly dried after cleaning, and well painted inside at intervals of two or three years, particularly round the angles and a few inches up the sides. This drying can easily be done by a coke brasier, or by shovels full of hot ashes spread over the bottom.

It is a mistake to fix tanks in out-of-the-way or inaccessible positions in roofs, &c., because they are sure to be neglected in such places, and a leak or overflow may do much damage to ceilings and furniture below. Frost may set fast the ball tap, close up the overflow or burst the pipes, or the water become fouled by dead rats or birds, &c., undiscovered for want of examination.

SECTION XI.—*PRESSES.*

CHAPTER XLV.

SCREW AND HYDRAULIC PRESSES.

THE operations of compressing goods into a minimum space and of expressing oils, shaping metals by pressure and similar uses in the mechanical arts, are now performed by a greater variety of machines than formerly, and their applications to such purposes have greatly increased. Before the hydraulic press was invented by Bramah, the screw press was practically the only mechanical device in use for these purposes; now we have besides these two, lever presses, fly presses, "Boomer" or lever and screw compound presses, besides numerous combinations of these types for special purposes.

In nearly all cases pressure is required to increase gradually up to the maximum, and all these varieties of presses are designed to act in this way.

In the general structure of any press we find in all cases a moving table "follower" or "platen" a corresponding head, base and tie rods. These parts are necessarily massive in proportion to the strains and rarely sustain any injury. For hydraulic presses the dimensions and proportions are given in a table below, and similar dimensions may be adopted for screw or other presses for equal powers.

Screw Presses.—A screw and nut seems to be the simplest contrivance for converting low power and quick speed into high power and slow speed; but this is done in practice at a heavy loss for friction. In any screw press it may be

assumed that fully one-third the useful effect is lost in this way, and this percentage increases with the pressure and with the pitch of the screw. As, therefore, friction means wear and tear, we find in fact that the wear of the screw nuts is considerable, that of the screws is less, because of the more extended surface in work. Square thread screws are almost invariable; wooden screws, usually of beech, are, however, necessarily made with a V thread, and for iron or steel the most economical thread is that shown in Fig. 376, as a shorter pitch can be used with equal strength of thread as compared to a square one.

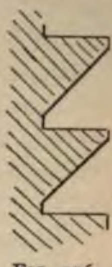


FIG. 376.

Hydraulic presses apply their pressure by a cylinder and ram, the head of the latter being secured to the platen or follower, and its stroke is equal to the range of motion required in the follower. The following table gives the dimensions of presses, up to 400 tons pressure, as usually constructed.

DIMENSIONS OF HYDRAULIC PRESSES (Fig. 377).

ons.	A varies for different lengths.				Dimensions in inches.												Area of Ram. sq. in.	Thickness of Cylinder.
	1′–4′	4′–7′	7′–10′	10′–13′	B	D	E	F	H	I	J	K	L	M	N	P		
10	1½	1¾	2	—	1¼	2½	2¼	¾	1¾	4	4	4	4¼	4¼	⅞	2¼	= Total pressure in tons / Pressure per square inch in tons × 1·6	See Tables, pp. 428 and 429.
15	1½	1¾	2	—	1⅜	2½	2⅜	¾	1⅞	5¼	5⅜	5⅜	5⅜	5⅝	1 1/32	3		
20	1½	1¾	2	—	1⅜	2½	2⅜	¾	1⅞	5⅞	5⅝	5⅝	5¾	5¾	1 1/32	3 3/16		
30	1½	1¾	2	—	1½	2½	2⅝	¾	2	6¼	7 1/16	7	7⅛	7¼	1 1/32	3¼		
40	1¾	2	2¼	2½	1⅝	3	2¾	¾	2¼	7	7½	7½	7¾	7½	1⅝	4		
50	1¾	2	2¼	2½	1¾	3	2⅞	¾	2⅜	7¼	7⅞	7⅞	8⅛	8⅛	1¾	4 3/16		
60	1¾	2	2¼	2½	1⅞	3	3	⅞	2½	7½	7⅞	7⅞	8¼	8¼	2	4½		
70	2	2¼	2½	2¾	2	3¼	3¼	⅞	2¾	8	8	8	8⅜	8⅜	2⅛	4⅝		
80	2⅛	2¼	2½	2¾	2⅛	3¼	3⅜	⅞	2¾	8	9⅜	9⅜	10⅜	10⅜	2¾	4¾		
00	2¼	2⅜	2½	2¾	2¼	3¼	3⅝	⅞	3	8⅛	12	12	12 3/16	12 3/16	2¾	4¾		
50	2⅝	2¾	3	3¼	2⅝	3¼	4	1	3½	8⅞	12½	12½	12¼	12¼	3	4⅞		
00	3	3	3	3½	3	3¾	4¼	1	4	11½	14⅜	14⅜	15¼	15¼	3	5½		
00	3½	3½	3½	3½	3½	4⅝	4⅞	1	4¾	12	15	15	16	16	4	6		
00	4	4	4	4	4½	5¼	6⅛	1⅛	5⅜	13	16	16	18	18	4	6½		

The ram is either a solid or hollow cylindrical plunger, turned true and parallel and polished. The cylinder is bored only in the neck, as Fig. 378, and the packing is a plain U or L section leather collar sunk in a turned groove (Figs. 379, 380). This packing is the only part requiring attention or renewal: there must be no joint in it, as it is quite impossible to make such a joint tight. The smooth or hair side of the leather is inside, and it is well saturated with grease, preferably Russian tallow.

To insert a new leather the press follower is either taken out or suspended to the press head, the ram lifted out, the

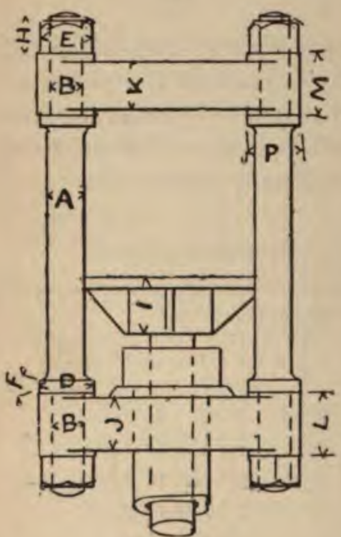


FIG. 377.

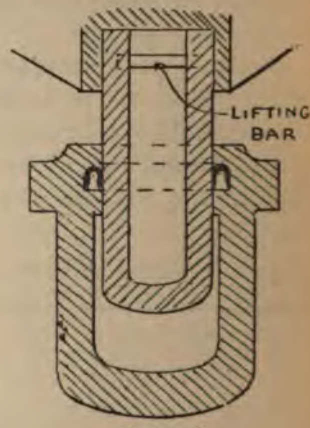


FIG. 378.

FIGS. 379, 380.

old collar removed and the new one got in by bending it as Fig. 381. Another method of inserting collars is shown in Fig. 382, where a gland is used; this avoids the necessity of raising the ram, as the collar can be slipped over the ram. The section of the collar may also be made as Fig. 383, in which case the joint depends on the gland being tightened down hard.

These leathers are made from the best hides, from which circular pieces are cut about 1 inch too large every way, and after steeping in water till soft are thoroughly greased and forced into a die shaped as Figs. 384 and 385, and left to dry under pressure, when the surplus ragged edges are trimmed

Fig. 381.

Fig. 382.

Fig. 383.

off and the edges bevelled as Figs. 379 and 380; any cracks at the bend are sure to leak. It must be remembered that water will pass through all the substance of the leather except its smooth or hair side, and if this is injured the leather is useless. Hydraulic presses, to be worked rapidly, should be operated from an accumulator, which takes up the power of the

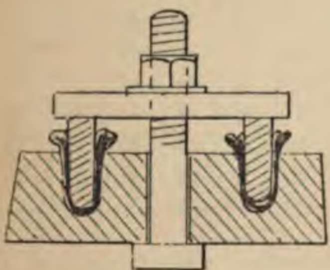


Fig. 384.

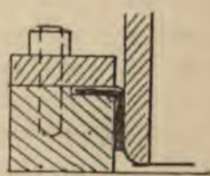


Fig. 385.

engine while the press is standing, and enables the press to be run up very quickly. Ordinarily, however, pumps are used which pump direct into the press cylinder.

Press connections, pipes and pumps are referred to on pp. 106–108.

THICKNESS OF CAST-STEEL HYDRAULIC CYLINDERS.

Inside diameter.	Tons per Square Inch. Test Pressure.											
	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3½	4	5
in.												
3	..	..	..	..	..	..	..	..	..	1	1⅛	1¼
3½	..	..	..	..	..	..	..	..	..	1⅛	1¼	1½
4	..	..	..	..	..	..	..	..	1	1¼	1⅜	1⅝
5	..	..	..	..	..	..	1⅛	1¼	1¼	1½	1⅝	2
6	..	..	..	..	1	1⅛	1¼	1⅜	1⅜	1⅝	1⅞	2¼
7	..	..	..	1	1⅛	1¼	1⅜	1½	1⅝	1⅞	2⅛	2⅝
8	..	..	1	1⅛	1¼	1⅜	1½	1⅝	1¾	2⅛	2⅜	3
9	..	1	1⅛	1¼	1⅜	1⅝	1¾	1⅞	2	2⅜	2⅝	3¼
10	..	1⅛	1¼	1⅜	1½	1¾	1⅞	2	2⅛	2½	2⅞	3⅜
11	1	1¼	1⅜	1½	1⅝	1⅞	2	2¼	2⅜	2¾	3⅛	4
12	1	1¼	1⅜	1⅝	1¾	2	2⅛	2⅜	2½	3	3⅜	4¼
13	1⅛	1⅜	1½	1¾	1⅞	2⅛	2⅜	2⅝	2¾	3¼	3¾	4⅝
14	1⅛	1⅜	1⅝	1⅞	2	2¼	2½	2¾	2⅞	3½	4	5
15	1¼	1½	1¾	2	2⅛	2⅜	2⅝	2⅞	3⅛	3¾	4¼	5¼
16	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3⅞	4½	5⅝
17	1⅜	1⅝	1⅞	2⅛	2⅜	2¾	3	3¼	3½	4⅛	4¾	6
18	1⅜	1¾	2	2¼	2½	2⅞	3⅛	3⅜	3⅝	4⅜	5	6¼
20	1½	1⅞	2⅛	2½	2¾	3⅛	3⅜	3¾	4	4¾	5½	7
22	1⅝	2	2⅜	2¾	3	3⅜	3⅝	4	4⅜	5¼	6	7⅝
24	1¾	2⅛	2½	2⅞	3¼	3⅝	4	4⅜	4¾	5⅝	6½	8¼
26	1⅞	3⅜	2¾	3⅛	3½	4	4⅜	4¾	5⅛	6⅛	7⅛	9
28	2	2½	2⅞	3⅜	3¾	4¼	4⅝	5⅛	5½	6⅝	7⅝	9⅝
30	2⅛	2⅝	3⅛	3⅝	4	4½	5	5½	5⅞	7	8⅛	10¼

Boomer Presses are constructed with horizontal screws which apply their pressure to the platen by diagonal links, the angle of which varies as the platen travels, so as to give an increasing pressure, and of course reduced speed of movement to the platen. They are therefore essentially screw presses; ordinary screw presses, however, do not give any gradual increase of pressure with proportionate reduction of speed; this is accomplished in the "Boomer" by the com-

THICKNESS OF CAST-IRON HYDRAULIC CYLINDERS.

Inside diameter.	Lbs. per Square Inch. Test Pressure.				Tons per Square Inch. Test Pressure.								
	800	1000	1200	1500	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3
in. 3	3/8	3/8	1/2	1/2	5/8	3/4	7/8	1 1/8	1 1/4	1 1/2	1 5/8	1 7/8	2
3 1/2	7/16	1/2	1/2	1/2	3/4	7/8	1	1 1/4	1 3/8	1 5/8	1 7/8	2 1/8	2 1/4
4	1/2	1/2	1/2	9/16	7/8	1	1 1/8	1 3/8	1 1/2	1 7/8	2 1/8	2 3/8	2 5/8
5	1/2	9/16	5/8	3/4	1	1 1/4	1 3/8	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3 1/8
6	1/2	5/8	5/8	3/4	1 1/8	1 3/8	1 5/8	2	2 1/4	2 5/8	3	3 3/8	3 3/4
7	9/16	5/8	3/4	7/8	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	3	3 1/2	3 7/8	4 1/4
8	9/16	3/4	7/8	1	1 3/8	1 3/4	2	2 1/2	2 7/8	3 3/8	3 7/8	4 3/8	4 7/8
9	5/8	3/4	7/8	1 1/8	1 1/2	1 7/8	2 1/4	2 3/4	3 1/4	3 7/8	4 3/8	4 7/8	5 3/8
10	3/4	7/8	1	1 1/8	1 5/8	2 1/8	2 1/2	3	3 1/2	4 1/4	4 3/4	5 3/8	6
11	3/4	7/8	1	1 1/4	1 3/4	2 1/4	2 3/4	3 3/8	3 7/8	4 5/8	5 1/4	6	6 1/8
12	7/8	1	1 1/8	1 3/8	2	2 1/2	3	3 5/8	4 1/4	5	5 3/4	6 1/2	7 1/8
13	7/8	1	1 1/4	1 1/2	2 1/8	2 3/4	3 1/4	3 7/8	4 1/2	5 3/8	6 1/8	7	7 3/4
14	7/8	1 1/8	1 1/4	1 1/2	2 1/4	2 7/8	3 3/8	4 1/8	4 7/8	5 3/4	6 5/8	7 1/2	8 1/4
15	1	1 1/8	1 3/8	1 5/8	2 3/8	3	3 5/8	4 1/2	5 1/4	6 1/8	7 1/8	8	8 7/8
16	1	1 1/4	1 1/2	1 3/4	2 1/2	3 1/4	3 7/8	4 3/4	5 1/2	6 1/2	7 1/2	8 1/2	9 1/2
17	1 1/8	1 1/4	1 1/2	1 7/8	2 5/8	3 3/8	4 1/8	5	5 7/8	7	8	9	10
18	1 1/8	1 3/8	1 5/8	2	2 3/4	3 5/8	4 3/8	5 3/8	6 1/4	7 3/8	8 3/8	9 1/2	10 1/2
20	1 1/4	1 1/2	1 3/4	2 1/8	3	3 7/8	4 3/4	5 7/8	6 7/8	8 1/8	9 3/8	10 5/8	11 3/4
22	1 3/8	1 3/8	1 7/8	2 3/8	3 3/8	4 3/8	5 1/4	6 3/8	7 1/2	8 7/8	10 1/4	11 5/8	12 7/8
24	1 5/8	1 5/8	2 1/8	2 1/2	3 5/8	4 3/4	5 3/4	7	8 1/4	9 3/4	11 1/8	12 5/8	14
26	1 1/2	1 7/8	2 1/4	2 3/4	3 7/8	5 1/8	6 1/4	7 5/8	8 7/8	10 1/2	12	13 5/8	15 1/8
28	1 5/8	2	2 3/8	2 7/8	4 1/4	5 1/2	6 5/8	8 1/8	9 1/2	11 1/4	13	14 5/8	16 1/4
30	1 3/4	2 1/8	2 5/8	3 1/8	4 1/2	5 7/8	7 1/8	8 3/4	10 1/4	12 1/8	13 7/8	15 5/8	17 3/8

pound links and centres, with a right and left-hand screw and two nuts.

Power is applied by fixing belt pulleys on the screw spindle, with open and crossed belts for up and down motions, and a hand shifting lever for controlling the belts. The wearing parts are the screws and nuts and the link centres; these involve no special treatment, however. The columns,

head, base and follower are of the same strengths as given in the table of hydraulic presses, p. 425.

Lever and other presses, generally used for hay, straw, dried moss, &c., are simply hand lever machines with toothed racks and pawls by which the press follower is retained at each application of the lever. This latter is a very long one with a short leverage, and gives a good pressure with, of course, very short movements of the follower. The process is slow, but one or two men can work such a machine with ease, and the first cost is low.

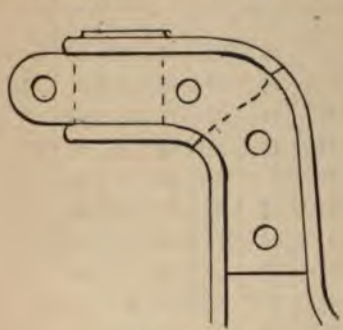


FIG. 386.

Fly presses are screw presses which multiply their power by the momentum of a fly or weighted lever in conjunction with a long pitched screw, and are used for punching, stamping and similar uses. The screws and nuts wear a good deal, and occasionally the press standard is broken by bringing the die down too hard on an unyielding material. The standards are of cast iron, but would be a great deal stronger if of wrought iron. In some few cases they can be repaired by wrought-iron cheeks or fish plates on each side bolted through the standard; such cheeks are not of much use if they depend only on the bolts, but where the casting is flanged or moulded, as Fig. 386, may be successfully employed.

SECTION XII.—*PRINTING MACHINES.*

CHAPTER XLVI.

CYLINDER MACHINES AND HAND PRESSES.

ALTHOUGH printing machines have made great strides in capacity and speed, this class of machines is singularly subject to traditional and conventional treatment, especially in details. Some of the most modern and improved machines contain still forms of gear that would never be tolerated in other machinery and, in fact, are contrary to common sense, as we shall presently show.

Although numerous specimens of the old "Spread Eagle" and Stanhope hand presses are still at work for printing posters, &c., the cylinder machine, driven by power, has become the type for general use, and the turnover platen machine the general type for job printing by hand or power. A printer's plant will also include guillotines, label and envelope making, gumming, eyeleting machines, and sometimes, also, stereotyping and lithography plants.

Cylinder printing machines are driven at high speeds, and from their complication and defective design frequently give a great deal of trouble. We have to complain that they are unbalanced more or less, a serious fault with high speeds. The tables are reciprocated also at high speed and without any satisfactory means of absorbing and giving out the momentum of such heavy moving parts. The strain thus put on the driving racks and wheels below is very great, resulting in frequent breakages.

The cylinders also are driven by racks on the tables with the teeth *upwards*, and the lower fixed driving rack also has

its teeth upwards, a very faulty detail, as is evidenced by the frequency with which these racks are broken; they are liable to catch and retain all rubbish and scraps of paper, which either jam the gear or break it. A further serious error of design is the number of open cams and springs employed for the movements. All these could be replaced by covered cams and the springs done away with. An open cam—where the lever or other movement is returned by a spring—has to do both movements in one—as it were—that is, the strain on the cam in lifting is double that needed to do the work plus the excess pressure of the spring. A covered cam, on the other hand, both lifts and returns its movement with only the actual strain of the work done either way, and the wear on the cam is both divided and reduced, while it avoids the possibility of the movement sticking through failure or insufficiency of the spring. The tremendous noise made by these machines is conclusive evidence that there is an immense amount of wear going on. A good deal of it is due to the inking rollers and their bearings, but the entire machine is, as a rule, a perfect rattletrap.

The machines are loaded with finished and bright parts, quite unnecessarily, as a rule, the cost of which might very well go to the purchase of more metal in many places, and better designed bearings and other details. Wear and tear are serious items, and the stoppages often resulting still more serious in losses and delays. The workmanship is, in general, very good. The gears are usually machine cut, and steel is largely used for centres, pins, links, &c., but in the design of these a great deal might be saved. We find, for instance, large centre pins having diameters—on one pin—varying from $\frac{7}{8}$ inch to 5 inches, involving a great deal of turning and waste of metal. Friction rollers also are common, that are not more than from $1\frac{3}{4}$ to twice the diameter of the pin they run on. We find, therefore, that they seldom turn round at all, and that they soon wear into flats and have to be renewed. Friction rollers—to ensure turning—should never be less than three times the diameter of the pin they run on, and as much more as possible.

The racks are frequently broken, sometimes from odd fragments or articles getting into the teeth, and sometimes from missing gear with the cylinder wheel from failure to catch the spring stop. This again is poor designing, to run a wheel in and out of gear with its rack; wear and backlash will in time ensure its failure, even if no other cause intervenes to accelerate it, but in some cylinder machines the stop motion will only act by momentum, and if the machine is run slowly may fail to act. The racks are secured by set screws to the table; these screws are liable to jar loose and, being between the teeth, cause fracture. There is also no abutment or end stop for the rack to thrust against, so that as it depends on its screws, they tend to loosen from the constant reversing of the strains.

Broken teeth in these racks and cylinder wheels can be repaired as shown on p. 253. The framing of these machines is badly designed also for getting in and out any of the driving gear; as a rule, nearly all the machines must be dismantled to get out the large spur wheels and crank pin. The inevitable backlash in a train of wheels, racks and connecting rod such as these—running backward and forward at great velocity, only partially balanced, and with no absorbing device to check the momentum at each end of the stroke—becomes a dangerous item, especially as only the looseness of the connecting rod, of all these slack parts, can be taken up by adjustment. The wear of the friction rollers and races under the table often causes the latter to become hollow, so that it will not take the impression evenly, the table then requires planing afresh. But it would be much more satisfactory if strong enough by back ribs to withstand all the strains and run on fewer guides; as it is, the table gives way to its supports: a case without a parallel in other machines of similar construction, such as a planing machine.

The inking rollers never run satisfactorily: their end bearings are simple slots in the machine frame, in which they rise and fall. They are liable to jump out, and in some machines are kept down by hook bolts and springs. Still,

the spindles of these rollers frequently get bent or broken off. New ends can be inserted as shown in Fig. 387.

These machines are subject to the same general repairs to worn brasses, journals, and other wearing parts as other machines, but these occasion no unusual difficulties, and if the design of the parts just referred to was satisfactory they would run with very little trouble and less noise than now.

Hand machines scarcely call for any mention here; they are run slowly and not subject to any great wear or strains; the pins, cams, friction rollers, bearings, &c. require attention at long intervals, but are simple jobs needing no description.

Continuous web machines seem likely to supersede all the other types in the future, and have already attained considerable fame for newspaper printing. In these machines there is no reciprocating table, the paper is printed from ordinary formes without cylinder movement, and on one or both sides as required, and in two colours. The absence of the reciprocating table and cylinder render them much quieter and much more reliable. They give far less trouble in repairs, print more rapidly, and cut off and deliver their sheets—folded if required—with greater certainty and fewer misprints; with the cylinder machines these wasters, torn and damaged sheets, often reach a heavy percentage of the whole. Single and double machines of this class are now being introduced for general job printing also, and in the future it would appear that all printing papers will be manufactured and supplied in rolls of various widths, and printed on continuous machines.

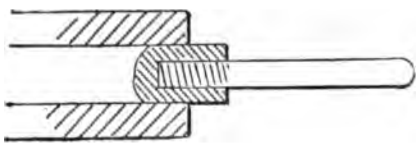


FIG. 387.

Guillotines or cutting-up machines do not, as a rule, give much trouble. The bolts about the machine sometimes give way, particularly those securing the knife to the cross-head or beam. They should be of steel, turned and fitted with lock nuts. The brake gear for checking the knife should be capable of being thrown on at any part of the stroke; in

some machines after starting, a whole down and up movement must be made before the brake will act; this leads to accidents. Hand machines require no self acting brake gear, but must be overbalanced so that the knife is always left at the top of its stroke. The knives must be ground straight and be well secured to the beam and supported on their upper edges to take the cutting strain off the bolts. There is no unusual wear on the working parts, which with ordinary care give no trouble.

Printing machinery should always, if possible, be driven from below, so that there are no overhead belts; and the belts and driving pulleys boxed in or protected.

The high speeds required necessitate strong and well fixed shafting, because the pulleys, speed cones and belts are all large and heavy.

SECTION XIII.

REPAIRING SHOPS AND TOOLS.

CHAPTER XLVII.

REPAIRING TOOLS.

IN an engineer's general business, repairing forms a considerable item, but does not involve many special tools or appliances beyond those employed for new work. But a good variety of outdoor and portable tools are necessary, and should be as handy as possible so that a repairer's kit may not be too clumsy.

These should include hammers and chisels (including light ones for the pocket) a simple selection of files, round, square and half round: ratchet braces and drills properly fitted to them. A *small* brace is very useful for all holes up to $\frac{3}{4}$ inch diameter. A portable cramp or drill stand for drilling by brace, such as Figs. 388 or 389, which can be used for any position and will take to pieces easily. These can be secured by an ordinary bolt and will swing to any angle. In many cases a wooden lever with a small centre plate can be used for odd holes and positions, with a hooked bar as Fig. 390. A flexible shaft and drill stock are very useful in out-of-the-way corners, and can be revolved by hand, or from any convenient shaft by a small belt.

A portable vice and bench, also a small powerful vice with clamp to secure to any existing bench or table.

A portable forge for riveted work and light forging. Very handy forms of this tool are made and are neither heavy nor bulky. Spanners and pipe tongs for outdoor jobs

should be chiefly adjustable ones for several sizes, otherwise a heavy assortment becomes needful if the ordinary ones are used. At most places where machines are running, all necessary spanners are kept, but are often also found to be very poor tools, so that they should not be depended on unless well

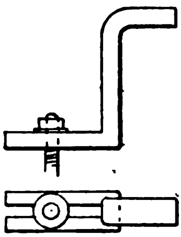


FIG. 388.

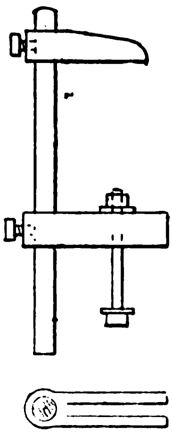


FIG. 389.

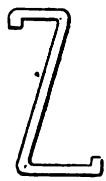


FIG. 390.

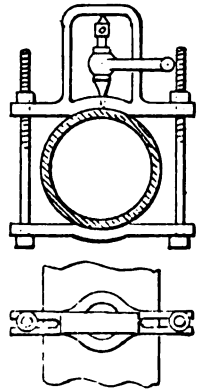


FIG. 391.

known. Screw hammers and other clumsy and useless types of the adjustable spanner should be thrown on the scrap heap. They generally are so heavy in the jaws as to be incapable of gripping nuts except in roomy positions.

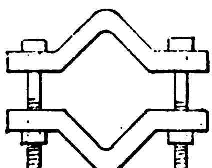
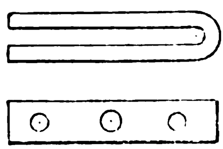


FIG. 392.



FIGS. 393, 394.

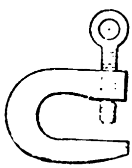


FIG. 395.

Bauer's spanners are good and take a considerable range, both of bolts and pipes.

Pipe drilling cramps for gas and water mains, to span the pipe (Fig. 391), need not be very heavy tools to be efficient.

Cramps of various forms, as shown in Figs. 392 to 395, are

very useful for temporarily securing articles of various sizes and shapes by bolts, &c.

Piston ring straps (Fig. 396) are used to compress the rings flush with the piston so that they will pass into the bore of a cylinder. Cramps as Fig. 392 can be used to hold up piston rods or suspend articles instead of rope slings.

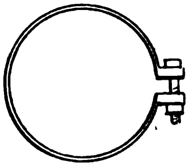


FIG. 396.

Short ropes and endless slings are required for slinging articles to be hoisted. Chains should be avoided as much as possible for this service as they slip on iron and are not so handy as ropes.

Chain blocks for hoisting are the best and safest ; Moore's or Weston's are generally preferred, but every erector should be well drilled in the strengths of ropes, chains and cross-bars or suspenders, and in the various methods of slinging before being trusted to much hoisting work. Many men

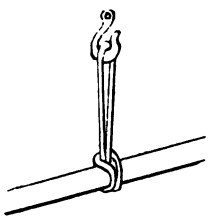


FIG. 397.

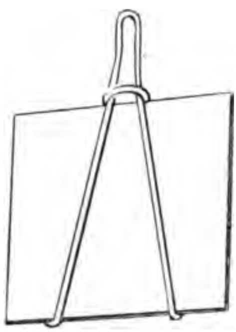


FIG. 398.

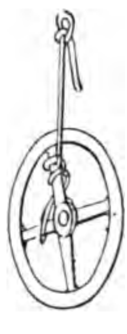


FIG. 399.

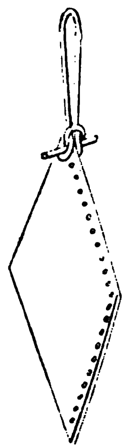


FIG. 400.

have only the most elementary notions on these points. Figs. 397 to 411 show the safest ways of slinging various articles. Long shafts or girders must be slung from both ends and the rope taken a turn or loop over the hook, or it is liable to slide along to one end and may cause an accident.

quare plates, &c. should not be slung by the corners, but s in two places as Fig. 398. Wheels are best held by the

FIG. 401.

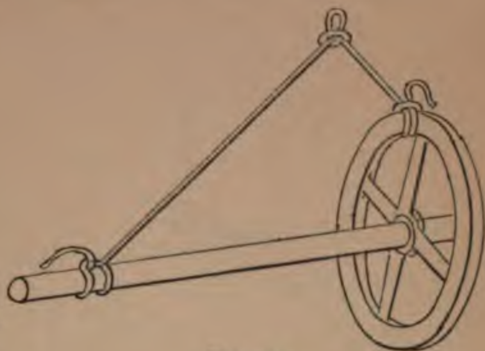


FIG. 403.

FIG. 404.

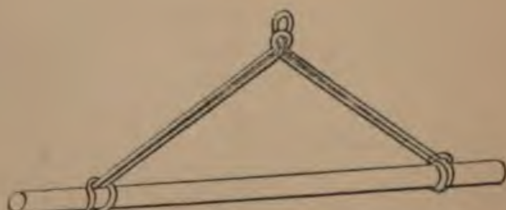


FIG. 405.

FIG. 407.

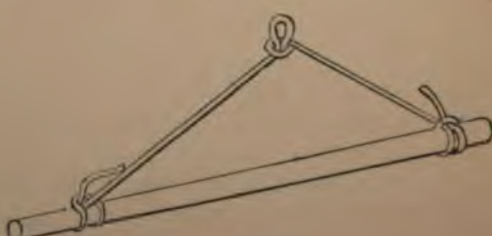


FIG. 408.

rim or the outer end of one arm. Boilers can be safely slung as Figs. 410 and 411, and sometimes can be best lifted by two pairs of blocks, one at each end. The Spanish windlass

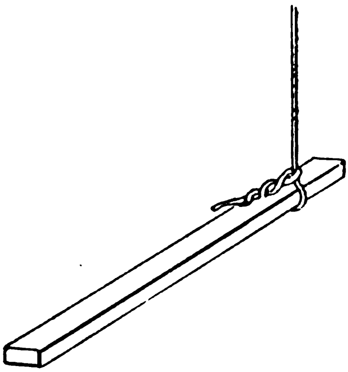


FIG. 409.

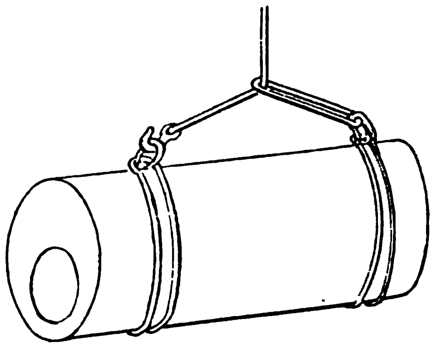


FIG. 410.

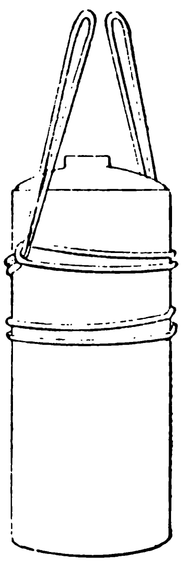


FIG. 411.

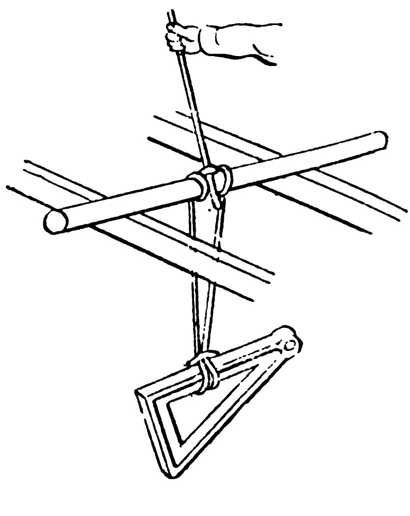


FIG. 412.

is occasionally useful where no other hoist is available, Fig. 412; it consists of a round bar, piece of scaffold pole or iron pipe and a piece of rope, through the looped end of which

a crowbar or similar article is put and the rope wound on the round bar by turning it with the crowbar. Several hundredweights can be raised this way.

All heavy details of machinery not of themselves capable—from their form—of being easily slung, ought to have either eye bolts, loops or screwed holes to which such attachments can be quickly applied. Hydraulic cylinders, rams, piston-rods, cylinder covers, pistons, air vessels and similar articles are very troublesome to lay hold of unless with these provisions.

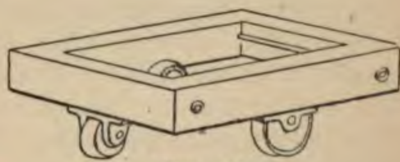


FIG. 413.

Large engines and marine engines have usually a simple form of overhead beam or traveller, provided either with a simple but powerful worm gear winch or with a hook for attachment of chain blocks for slinging any part of the engines. Pump wells also require cross beams for attachment of lifting gear, and steps and stages at various points in the depth for access to the pumps and valve boxes.

A simple form of low trolley to carry heavy articles is shown in Fig. 413; it has a single wheel at each end, slightly raised above the ground, and is thus very easy to swivel without any swivelling motion to the wheels.

A screw jack is sometimes required.

CHAPTER XLVIII.

REPAIRING SHOPS AND PLANT.

Repairing shops are now commonly attached to many works and factories employing much machinery, so as to deal at once with any repairs or breakdowns that arise.

The wisdom or policy of this plan is often called in question and with some reason; as far as economy in direct

cost of work done they are undoubtedly generally failures, because the work they have to do is very irregular and uncertain, at some times far exceeding their capacity, when of course some of it must be put out, at others just as far under the shop's capabilities. Then the men have to find something to do and *make work* somehow. This is the experience of all such repairing shops with very few exceptions; still, it is found that with such appliances and fitters at hand repairs are to some extent anticipated. There is no running off to a neigbouring or distant engineer's shop for aid, which may be inadequate through crush of work and other causes. There is also less difficulty in continuing the work all night and even on Sunday, to avoid delays, than when outside aid is depended on; and last, but not least, the machinery receives better general attention than can be given by the work-people, who will often run them under very improper conditions unless overlooked by an expert.

The fitters employed should be, however, men of considerable experience, and with these one or more lads and labourers are useful.

The plant for such a shop should comprise the following, in addition to the repairing tools referred to in Chapter XLVII.

A screw cutting and surfacing lathe, with gap bed of a size capable of taking in the largest articles likely to need repair.

A small lathe for odd articles.

A planing machine of capacity equal to any articles that may require planing. If these are, as frequently happens, of no great size, a good sized shaping machine is a much handier and more generally useful tool.

Drilling and boring can be done in the lathe in most cases, unless it is otherwise likely to be fairly employed, when it is desirable to have a drilling machine—size to be determined by the work likely to be done.

If a planing machine is purchased some kind of shaper is desirable. A hand shaper will in this case do a great variety of work and quickly, or a power shaper may be used, the larger the better.

Milling is seldom required, but can be done in the lathe, and slotting can be done generally in the shaper.

An emery machine is required for tool and other grinding.

One or two vices and a bench.

A screwing machine for hand use, and a set of stocks, dies, taps and wrenches for both Whitworth and gas threads.

Hammers, chisels, files, punches, key and other drifts; caulking tools.

A forge, anvil, swage block and stand, ordinary or special top and bottom swages, tongs, water trough, bellows and other smith's tools.

A crab winch if required, a screw jack, a surface table and a surface plate.

All the tools should be heavy, and be also conveniently arranged. Light tools are of no use.

SECTION XIV.—*LAUNDRY MACHINERY.*

CHAPTER XLIX.

ENGINES, BOILERS, ETC.

THE remarks already made with reference to the maintenance of shafting, gearing, pulleys and belting, apply equally to those used in laundries. It is, however, necessary to add that special precautions have to be taken to avoid rusting and the accumulation of oil and dirt. In these establishments the rooms are almost invariably full of steam and subject to considerable variations of temperature: two factors which are the best calculated to destroy shafting and ruin belting. The latter must be chosen of the best leather, must have a good margin of strength, and must be proof against excessive stretching when subjected to the above conditions. It is doubtful whether any amount of care will prevent the rusting up of the ironwork if it is continuously exposed to the atmosphere of these rooms. The surest preventive is to have all the gearing either boxed in or otherwise removed from the sources of corrosion. The shafting may be covered with white lead paint or some similar rust-preventive, and all wheels and pulleys thoroughly coated with good oil paint. This is a very important point, for rust is a most troublesome thing to have to contend with in a laundry.

All bearings and gear-wheels should be fitted with oil catchers (and splash guards where necessary). Oil spots are a great nuisance, besides being very unsightly if occurring on beams or on the floor. Every possible means to secure

cleanliness in the working of the machinery should be adopted.

The Engine should always be of more power than the immediate requirements of the work call for, not only because it is well to be prepared in this direction for additions to the machinery, but because it is necessary that the engine should run without any variation of speed under the many alternations of load which occur in the course of each hour's run. The collar ironing machines, the fan for the gas irons and the calenders should always be driven at a regular speed.

Laundrymen are very liable to get astray in this matter of motive power. For the sake of a few pounds an engine is used which is too small for its work from the beginning, and which costs a small fortune for repairs almost from the very day it is bought. It is quite inevitable that if an engine be overworked, either continuously or occasionally, all the working parts must suffer and the whole rapidly deteriorate, to say nothing of the indifferent duty performed. These remarks apply also to gas engines, which are now largely used and in which the effects of ill usage become more quickly apparent and are often only remediable at great expense.

The Boilers are a fruitful source of trouble in the laundry for two reasons: (1) they are rarely in the hands of a man competent to look after them; (2) very few people are aware of the large amount of work they have to perform. It is a serious mistake, often committed, to leave the boilers and engines in the care of a man who has also to look after the machines in the washhouse. The boilers inevitably suffer. Only first-class stokers will successfully manage a laundry boiler and keep steam and water level uniform. The demands made upon the evaporative power of the boiler are generally the least portion of its duty. An enormous quantity of hot water, in many cases, is drawn off in the course of the day, and very often little or no provision in the capacity of the boiler has been made to meet this. Great fluctuations in the water level and the temperature of the water can only be avoided by very skilful handling: we

insist upon this point, because many lives depend upon the care or want of care exercised in this direction.

Portable or multitubular boilers are to be avoided in laundries for the reasons given, and because they are less accessible and more liable to injury from large feeds of cold water.

Undoubtedly the proper means of meeting this difficulty is to have an efficient feed water heater. Many of the leaks on the boiler shells are due solely to the excessive strain caused by the frequent introductions into the boiler of several hundred gallons of cold water. In any case a distributing feed pipe should be fixed in the boiler, as far removed from the fire as possible, just below the surface of the water and as far from the boiler shell as can be arranged.

The natural sequence of this sudden lowering of the temperature of the boiler is excessive firing. It is a common thing to see a large pile of burnt up fire-bars in a laundry yard. These bars have been destroyed before their time, owing to the vicious practice of maintaining great fires under the boilers to compensate for the fluctuations in the pressure and feed. The leaks which disfigure the boiler face and all the fittings are also primarily due to these irregularities, and no amount of caulking or packing will remedy them if the abuses be continued. A further consequence of this large demand for hot water is the creation of a large amount of sediment in the boilers, an amount which appears excessive compared with the evaporation of the boiler, and is only accounted for when the hot-water supply is taken into consideration. The boilers should be frequently blown off—partially every day and thoroughly at short intervals. Where the water is hard this becomes an imperative duty, for if hard firing be indulged in under a boiler which has much sediment in it, the plates will bulge and an explosion is by no means impossible.

It may be said generally that the practice of drawing hot water direct from the boiler is a bad one, as well as most expensive. A large feed-water heater utilising the exhaust steam from the engine or hydros should be provided, so as to be equal to the greatest demand for hot water that is likely

to be made. This not only saves the boiler and fuel, but allows of a smaller one being used.

Artificial draught forcing apparatus should only be used on boilers with ample margin of power and in the care of a good fireman, otherwise overheating and its concomitant dangers will be accentuated; for these appliances, in the hands of an indifferent attendant, will simply become another means for unduly taxing the boiler's powers. *Never use them to increase your steaming capacity*, they should be regarded strictly as economisers of fuel only.

The steam should be as dry as possible,—wet steam is ineffective and costly—all the pipes of large diameter, with bends, *not elbows*, and well covered to prevent radiation. Steam traps should be inserted in long pipes to collect the water, and the pipes should be fixed with a slight inclination to the traps, so as to assist the flow of the water in the right direction (see Chapter XLIII.)

The pumps to feed the boiler should always be in duplicate, or if an injector is generally used, a pump must be kept in reserve in case of breakdowns (see Chapter III.)

If a feed heating apparatus is employed, the pumps may be large with advantage and security; but if the feed be used cold, the pump should be smaller, to minimise the dangers already mentioned. A small pump necessitates continuous and regular feeding; while with a large one there is a tendency to leave matters till the last moment, and then fill the boiler with a rush. The hot water supply pipe from the boiler to the washhouse should be fitted with a stop cock in the boiler house, so that the fireman can check the flow of water from the boiler if the level is getting dangerously low.

A large amount of general information concerning boilers will be found in Chapters I.–III.

Washing Machines.—Of the machines in the washhouse the washing machines demand first attention. These are generally of three types: the horizontal, the vertical rotary and the reciprocating machines. There are a few designs of machines which do not come under the above heads, but there is no other *type* of washer.

The horizontal rotary washer consists of a cage and an external casing, either or both of which revolve. These machines are not liable to any very serious breakdowns, the worst that happens usually being the fracture of two or three teeth in one of the spur wheels. This kind of breakage is most often caused by the use of the catch which is generally provided for fixing the cage when filling and emptying. The catch is thrown into gear before the machine has stopped, and it is only a matter of time before either it or the teeth of the wheel give way. It is a very crude method of accomplishing the end desired, and the sooner makers adopt a friction strap or other more flexible appliance, the better for the laundryman. In the event of the catch breaking, one with a spring attachment to the casing of the machine or a block brake to the wheel would be better than a duplicate of the original catch.

If the spur wheel breaks it becomes a matter for consideration whether it will be cheaper and more expedient to get a new one in preference to repairing the old one. In the majority of cases it will be better to send for a new one, whether the wheel be repaired or not. Repaired wheels often break again in a short time, owing to their having lost their true symmetrical form. If one or two teeth are broken, gun-metal ones should be inserted in the rim, as described on page 253.

The water gauge glass is liable to become broken. In this case a wire guard, or better, a brass guard similar to those used on steam fittings, will save trouble in the future. Care should be taken that the escape valves on those machines which are practically steam tight are in good working order, as they constitute the only safeguard against a dangerous accumulation of pressure. They should be tried every day.

Repairs to the cage, whether it be of galvanised iron, brass or gun metal, should be carried out in gun metal, and copper rivets or bolts used. In the case of galvanised cages, care must be exercised not to remove any of the zinc coating from the parts, otherwise corrosion will set in and work its way *under* the coating, which will soon drop off like rust or scale.

and leave the iron bare. Wooden cages should have gun-metal straps and copper bolts. Gun-metal should be used in preference to brass for all the internal parts of washing machines, because it is very much less liable to corrosion.

If the cage is only keyed on to the trunnion it will probably work loose. The keys must be supplemented by pins or set screws, which go right through the shaft and thus make it practically impossible for the cage to slip round. Once every day the interior should be thoroughly cleaned with a fairly strong soda solution. This will not only secure cleanliness in working but will add to the life of the machine.

If a stave in a wood cage is much worn it should be promptly replaced. It is a mistake to let the cage run till it is all to pieces, it will last much longer and will not be so rough on the linen if it be kept continuously in good repair. Strong tie bolts should always be used, or the two ends of the cage will very likely shift their relative positions, and the staves of the cage become all on the skew. Metal ends are much to be recommended in place of wood.

Vertical rotaries usually have no cages, but a series of wooden vanes fixed to the spindles. These machines are not much used in large laundries as they are too destructive to the linen, and in large sizes would become unmanageable. Owing to the risk attendant on oiling the bearings of the upright spindle, which would conduct the oil direct into the washer, these machines are allowed to run dry, and consequently develop into rattletraps in a very short time. The only repairs required are the occasional replacing of the wooden vanes, and the still more occasional repairs to broken gear wheels. To prevent the oil running down into the washer, a cup may be turned out of the solid, on the shaft underneath the bearing; or a cup may be brazed on to the shaft. Care must be taken, however or, with careless oiling, this remedy will prove worse than the disease, for the oil will syphon over the top of the cup long before it becomes full, unless cleaned out.

The reciprocating washers are preferred by many who do not approve of the closed vessel peculiar to the other types.

They are much used for flannels and linen which requires watching during the cleansing process.

Generally speaking, they consist of one or more rocking shafts, with a number of levers and links to which are attached wooden rubbers, working in a suitable receptacle somewhat like a wide shallow trough. Unless all these links, &c. are made with large eyes and fitted with large pins, the machine soon gives trouble and becomes noisy. It is best to have the eyes bored out as large as they will allow, and correspondingly larger pins used (not bushes). There is very little motion at any of these joints, and bushes or brasses are not necessary.

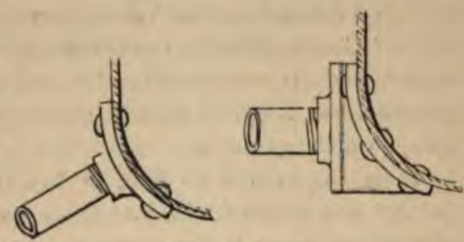
The older kinds of washers, using stamps and punches, are out of date now, and it is wiser to get a more modern machine than to waste time and money on them in repairs. Pitch pine is generally used for the wood-work of all washers, because of its durability. White pine is, however, the wood for the very best work. It is a cleaner wood, and being softer, does not scrub the linen so much. New pitch pine work must be well soaked and boiled before being used for linen.

The oiling of all washing machines requires considerable care. Too little oil is useless, and too much means trouble for the washerwomen. The machines should only be oiled when running, and all surplus oil wiped off with a rag. In the case of vertical spindles, Stauffer's solid lubricant and lubricators should be used; this also applies to suspended hydros.

The reversing gear on most machines is too light. If any portion of it breaks it is advisable to have a wrought-iron piece made to take its place; the additional expense is very little, and is very soon saved. The bolts and set-screws in these gears and in many laundry machines are often allowed to remain loose for several days. This is very bad supervision, and is generally the result of incompetence, or because the engineer, competent enough, has too much wash-house duty on his hands to be able to properly look after his machinery.

The steam connections are generally made with a thread and a backnut; a flange, however, is infinitely better. It

may be bent to the curve of the casing if it is to go on the cylindrical part, or a block can be fixed first. An asbestos joint-piece, blackleaded on each side, makes the best joint—a joint which can be broken several times without destroying the joint-piece (Figs. 414 and 415). Where the steam pipe enters through the trunnions, and thus a gland is necessary, the gland should be made very deep. It is a mistake to tighten up glands so hard, as is usually done—it often results in a fractured steam pipe, and some one may be scalded. If the packing be from two to two and a half times in depth the diameter of the shaft, no excessive tightening up will be necessary.



FIGS. 414, 415.

CHAPTER L.

HYDRO-EXTRACTORS.

Hydro-extractors are either over- or under-driven, and either direct or by belting and friction gear. The self-contained hydro is undoubtedly the best and the handiest, and if well looked after will give much less trouble than a belt-driven one.

The foundation for a hydro is a very important factor; unless the machine is truly set and quite level it will not work properly. To run a hydro that has been fixed with its spindle out of perpendicular is just as bad as if it were run improperly loaded, and will give rise to the same troubles. Belt-driven machines should be set on a deep bed of concrete

or of good bricks set in cement; and long foundation bolts set in the bed should be used for bolting the framing down. No wedges, whether wood or iron, must be used to adjust the level of the machine. *It must be set direct on to the cement of the bed* so that vibration cannot destroy its adjustments. Some self-driven machines are balanced, and do not require a deep foundation; the bed must be firm and true nevertheless: a hydro should never be fixed on a floor, but always on the ground.

It is impossible to load a hydro perfectly, and consequently the brasses will inevitably wear out of truth. The general tendency is for them to wear bell-mouthed longitudinally, and oval in the direction of the pull of the belt or engine, as Fig. 416. This kind of wear can only be remedied for a short time by taking up the brasses: they must be re-

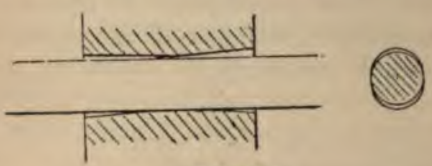


FIG. 416.

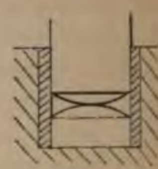


FIG. 417.

bored to secure a good fit again. It is well to have duplicate sets of brasses to avoid loss of time. If the brasses are suitable they may be changed end for end and turned half round, so as to counteract the wear; this will save knocking for a time, but is only a makeshift, and not to be recommended.

The bottom end of under-driven hydro spindles and the load collar on over-driven ones, will often give trouble until their vagaries are understood. Some will heat if they are too finely adjusted, some if they are too loose, and, generally speaking, no two will behave alike. Those which have roller bearings or hardened steel toe-pieces (Fig. 417) must be kept well and *cleanly* lubricated, or they will grind and cut into each other in an incredibly short space of time. Spare discs and rollers or balls should always be kept, and the bearings occasionally overhauled and cleaned right out. If a roller or

ball shows more wear than the others it should be removed and another one put in its place. The belts should be kept very clean, especially in over-driven machines; in fact the utmost cleanliness must be observed in everything connected with the hydro. It is a good plan to have lids fitted to all the hydros to keep out the dust and oil.

In balanced hydros, the springs, after being once set, should not require further attention. If they do it is likely that a spring is faulty. A balanced hydro should run perfectly steady when empty; if it does not, it will not run steady when full. The proper way to test and adjust a hydro is when it is empty and running at full speed. Balanced hydros must be carefully loaded, and any tendency to undue vibration rectified by shifting the load. It must not be supposed that the bearings of balanced hydros will wear better than those of ordinary ones with indifferent attention. On the contrary, unless special care is given to their adjustment they will cut and wear in an incredibly short space of time. The slightest tendency to wobbling when tested empty or full should be at once rectified.

Perforated cages are the best—and copper ones best of all for laundries. These rarely give any trouble. In the wired ones care should be taken that no ends of wire become loose, or torn clothes and possibly cut hands will result. Like the washer, a daily dose of soda solution will keep the interior clean and in good condition.

Wringing machines do not vary much in design. The springs are either spiral or laminated, and in either case generally last out the machine. They are almost invariably unnecessarily strong, because the tenants of the washhouse will insist on putting on three times as much pressure as is necessary and advisable. It is a mistake to suppose that so much pressure is required: what is necessary is a better manipulation of the work as it passes through the rollers. It should be distributed along the full length, instead of being forced through in a bunch in the middle.

Rollers should not be allowed to become very much worn. A great loss of time and power is incurred, as well as

considerable wear on the linen. The wringer should *never* be used for any work that can be done in the hydro.

Wringers are very liable to become noisy on account of the form of the teeth of the gear wheels. Very little can be done to remedy this, save the adoption of large rollers—as large in diameter as can be inserted—and driving at a slower speed. Lubrication is difficult and not of very much use, as the whole machine gets wet while at work. The gear *must* be boxed in; in fact all gearing should be securely protected in a laundry. Women are more liable to accidents than men, and their clothes are more likely to be caught. The belts to a wringer should be wiped occasionally to keep them clean and dry. A wet belt will give much trouble, staining everything near it with brown spots.

Tanks.—The best way to repair an iron copper is to get a new one! Copper ones may be patched, but when once patching becomes necessary it is evident the metal is getting thin and it is time to think of getting another.

Wooden tanks, when badly made, or old or dry, will leak. If they do not "take up" in a day or two after being filled, the chances are they never will. The best white pine is the proper material for these utensils, but pitch pine is largely used now. The joints are tongued and put together with white lead, and any caulking that is done should be executed with hemp soaked in white lead; caulking is, however, a sign of bad workmanship, and a caulked tank should be valued accordingly. Tanks, whether of wood or iron, should be raised a few inches off the floor to prevent the bottoms rotting. It is a good plan to have the bottoms tarred or painted.

Before repairing a tank it should be left a few days to get partially dry, otherwise difficulty will be experienced in getting the joints tight afterwards (see also Chapter XLIV).

Trollies.—When trollies require new wheels, if they will allow of it have wheels 12 inches to 18 inches diameter put on them, and india-rubber tyres. They will run very much better and quieter.

Calendering machines are mostly of the "Decoudun" type with a cylinder, felted or otherwise coated, running in a

crescent which is polished on the face in contact with the revolving cylinder. The important exceptions are: the "Crabtree" machine, which has an endless felt running over the polished face of a segment of a circle; and the "Tullis" or "Hagen," which is practically a series of four small "Decouduns" grouped together. There are one or two machines similar to the "Fabian," in which the bed or crescent is over the cylinder. These may be regarded as inverted "Decouduns."

In all these machines the adjustment of the two surfaces in contact is the most important point in their satisfactory working. Once this is determined, they will often run for weeks without any trouble. The tension or pressure is generally obtained by means of springs, and only practice will enable a man to tell whether he has tightened up equally all round. The linen passed through it will show by the varying degree of polish if these adjustments have been correctly made; and it is really only by studying the linen as it comes through, that perfect adjustments *can* be made. Another important point is the steam pressure or temperature. This must be kept quite steady, for it will be found that if the machine be adjusted to run at say 20 lbs. steam pressure, it will not run with 15 lbs. This is often the reason why the machine tender finds himself at fault. A given pressure of steam will be found to suit a given quantity of starch in the linen. If the pressure of steam be lowered it will be found that the linen will stick and tear, and if it be raised too high the linen will come out limp.

The steam trap should always be in good order, so that no water can collect in the machine. A quantity of water in the bottom of the crescent will lower the temperature sufficiently to make the linen stick and sometimes tear. The water pipe from the crescent should, of course, lead from the lowest point, either directly or by a syphon pipe inside. The cylinder should be given a slight inclination, ¼ inch or so, to the trap end, so that the water will all run to that point.

If a leak occurs in the crescent or cylinder it is advisable to let it alone until it becomes so bad that it must be stopped;

then the whole joint must be remade. No half measures are of any use; caulking or wedging will only make it worse and perhaps start several other leaks. The joint should be made with stiff red lead and a grummet, or a thin copper or lead wire, very carefully and evenly laid and well jointed together—it is often at the joint in the grummet or wire that the leak occurs.

The cylinder or segment should always be lifted or turned up out of the crescent or felt after work. This prevents the moisture in the felt from rusting the bright faces, and also takes the tension off the felt and parts of the machine. Any starch or dirt which has collected on the faces should be scraped off with a knife. To polish the faces, a rag dipped in turpentine and used while the machine is hot is the best.

If a piece of linen gets stuck in the machine, it (the machine) must be stopped and reversed at once. This will often draw the article out, but if it does not, the cylinder must be raised and the linen pulled out by hand. The condition of the machine, the tension and the steam pressure at the time of the stoppage should be noticed, as this will often give a clue to the cause. Linen if it is too wet should not be put through a machine. The risk of tearing is great and the linen is partially destroyed in any case. Neither should the steam pressure be excessive. The *lower* the pressure at which the machine will run, the better the work done.

In the "Decoudun" type of machine, including the "Tullis," it is important to have the exact amount of felt on the cylinder so that it fits the crescent properly; too much will tear the linen and put a great strain on the driving gear; too little will give no finish.

The gearing is very liable to get into a filthy condition, owing to the dust from the felt and the linen adhering to the oily portions. Cleanliness should be insisted on, as the oil, assisted in its progress by the dust, will gradually travel all over the ends of the machine, and end by soiling any linen that is either the full width of the machine or that is put in near the ends.

In the rare case of a breakdown of the end framing, a smith should be called in and instructed to repair the fracture with bar iron plates, bent to the approximate shape and bolted firmly on. A good smith will repair a simple fracture in a very short time. The holes for the bolts in the frame will generally have to be drilled with a brace, and can be done while the smith is getting the plates ready.

In the "Crabtree" machine the felt requires skilful handling; it should never be stretched too tightly, especially when new. A mistake is often made in getting the felts too small at first; they are sure to shrink, and if tight at the commencement will split in a few days. Felts split in the direction of travel; they should be sewn up with stout worsted thread directly the fracture begins to show. If properly done at once, a felt will often last for weeks without any further splitting. The polish in this machine is secured by modifying the tension of the intermediate rollers. Generally speaking, it will be found that the best work will be done and the felt last longest with little or no pressure on the lower rollers, but most on the delivery one. A mistake is often made by putting too much tension on the felt itself by means of the regulating roller. No more tension should be put on the felt than is necessary to keep it travelling on the other rollers. This is an important point.

Glands like those for the steam connections to washing machines should be as deep as possible in the trunnions of calenders, and tight screwing up avoided. A steam gauge and reducing valve should also be attached to every machine, not a reducing valve only.

Collar ironing machines do not vary much in design. They are mostly constructed with a reciprocating table and polished roller; there is a machine made with a radial fixed table and reciprocating roller. These do not often come to grief; they have not a great deal to do, and the greatest part of the wear falls on the teeth of the wheels.

The spring for the reversing gear should be kept well in tension, or the table will not reciprocate promptly. It should be made as long as possible—short springs soon wear out in

tension, and are also liable to break. Take care also that the belts run well on to the fixed pulley.

The hot roller requires frequent lubrication, or it will speedily run dry. Graphite and oil or some solid lubricative agent would very probably be useful for this purpose. The roller may be cleaned while hot, with a soft rag and turpentine.

The adjustment of the gas jet is a matter of experience, and depends a good deal on the air supply. If the machine has a separate fan, its supply can be regulated best by having a sort of by-pass valve which will allow of more or less of the air leaking away without reaching the jet. This method is easier than trying to regulate the speed of the fan.

While speaking of fans it will be as well to say here that they are almost invariably too small for their work. Small fans have to be driven at a high speed and make an objectionable humming noise (which may be heard in almost every laundry). They are also very irregular in their work. A larger fan may be driven slowly and quietly, and will give a steady, uniform volume and pressure of air. When fixing a fan it should be placed where there can be little vibration, and also—which is very important—where the air supply is as pure as possible. In some laundries the fans are so placed that they draw in dust and dirt and distribute it over the ironing rooms, making it difficult for the women to turn out clean work and keep it clean. A receiver or reservoir placed in the air-pipe near the fan, will not only serve to regulate the flow of air but will catch any dust that may be drawn in by the fan.

The gas irons require periodical cleaning, otherwise they will smoke, get cold and "sing." The singing of an iron is not always due to the air supply. The usual method of regulating the air supply to the irons is to have an aperture in the pipe which can be partially or wholly closed as required. A valve, as before described, would be more permanent and satisfactory. At present gas-irons and their appurtenances seem to be fixed entirely according to rule of thumb. Large fans and few irons, and small fans and many irons, may be

found in laundries next door to each other. There must be a considerable loss of power in one instance and of gas in the other, and laundrymen would do well to examine their irons and get a thorough hold of the correct principles of gas and air burners.

The pressure of air depends upon the pressure of the gas supply, and should not exceed two-thirds of the latter; the quantity of air depends on the quality of the gas, and may vary from 3 to 7 to 1. The form of the gas and air union is important: it should approximate as nearly as possible to the action of an injector, the gas and air meeting at an angle in the same direction.

The numerous minor machines of the ironing-room do not call for any special attention, as their working depends entirely upon the proper adjustment of the gas jet already discussed.

The ironing stove generally suffers from indifferent stoking. Repairs are unprofitable and are not recommended. The separate tiers can always be got from the maker on specifying the size and the number of the tier. Care should be taken that the chimney of the stove is well removed from any woodwork; fires most often originate from these stoves.

The old style of drying-horses is dying out now. They are insanitary and very cumbersome. Leaks in the pipework are often occurring and are dealt with in the usual way. A fan should always be used for exhausting the chamber, as it is liable to become very close and unhealthy from the steaming clothes. In the more modern method, a large quantity of air is circulated at a more moderate temperature, and there is not much gear to get out of order. Care should be exercised not to burn out the tubes of the heating furnace. Some firms make heaters on the same principle, using live or exhaust steam instead of a fire.

The commonest error met with in connection with drying-rooms is in connection with the temperature. The air should be circulated as cool as possible, not as hot as possible. Large quantities of cool air will dry the linen rapidly and leave it sweet, without the stuffy, nasty smell which is

characteristic of linen dried in the ordinary hot room; really a linen-oven!

Fans should be placed so as to drive the air into the rooms, not to exhaust it, except in the case of those used simply for ventilation, which are usually placed with regard to convenience only.

Mangles are the most antiquated machines in the laundry; they are just as crude and unmechanical as ever they were. Beyond the occasional breakage of a wheel or the fracture of the chain, they do not call for much attention. Here, as in all the other machines, the lubrication should be properly looked after. It looks very bad to see large spots of black grease on the top of the box, a by no means uncommon spectacle.

The teeth of the wheels may generally be repaired by the insertion of a stud, tapped in and filed to the shape of the tooth. The chain links and pins are easily duplicated by an ordinary smith.

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